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LANDSCAPE FEATURES AND ATTRACTANTS THAT PREDISPOSE GRIZZLY
BEARS TO RISK OF CONFLICTS WITH HUMANS: A SPATIAL AND TEMPORAL
ANALYSIS ON PRIVATELY OWNED AGRICULTURAL LAND

by

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B.A., St. Lawrence University, 1992

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Presented in partial fulfillment of the requirements

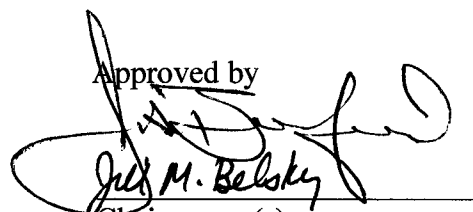
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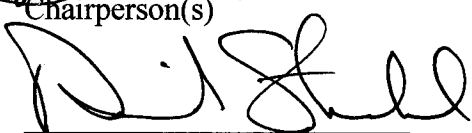
Doctor of Philosophy

The University of Montana

2003

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Chairperson(s)


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Landscape features and attractants that predispose grizzly bears to risk of conflicts with humans: A spatial and temporal analysis on privately owned agricultural land (219 pp.)



Director(s): James A. Burchfield, Jill M. Belsky

Grizzly bear (*Ursus arctos*) deaths in the US tend to be concentrated on the periphery of core habitats. These deaths were often preceded by conflicts with humans. Management removals of “nuisance” and or habituated grizzly bears are a leading cause of death in many populations. This exploratory study focuses on the conditions that lead to human-grizzly bear conflicts on private lands near core habitat. I examined spatial associations among reported human-grizzly bear conflicts during 1986-2001, landscape features, and agricultural-attractants in north-central Montana. I surveyed 61 of a possible 64 active livestock related land users and I used geographic information system (GIS) techniques to collect information on cattle and sheep pasture locations, seasons of use, and bone yard (carcass dumps) and beehive locations. I used GIS spatial analyses, univariate tests, and logistic regression models to explore the associations among conflicts, landscape features, and attractants.

A majority (75%) of conflicts were found in distinct seasonal conflict hotspots. Conflict hotspots with spatial overlap were associated with riparian vegetation, bone yards, and beehives in close proximity to one another and accounted for 62% of all conflicts. Consistently available seasonal attractants in overlapping hotspots such as calving areas, sheep lambing areas and spring, summer, and fall sheep and cattle pastures appear to perpetuate the occurrence of conflicts. I found that lambing areas and spring and summer sheep pastures were strongly associated with conflict locations as were cattle calving areas, spring cow/calf pastures, fall pastures, and bone yards. Logistic regression modeling revealed that the presence of riparian vegetation within a 1.6 km search radius strongly influenced the likelihood of conflict. After controlling for riparian vegetation, I found that unmanaged bone yards, unfenced and fenced beehives, all increased the odds of conflict. For every 1 km moved away from spring, summer, and fall sheep and cattle pastures, the odds of conflict decreased. The model confirmed the existence of conflict hotspots and illustrated that a collection of attractants beyond the effects of riparian vegetation were associated with conflicts. Contour probability plots of logistic regression models showed good predictive capacity. We discuss these findings and offer management recommendations.

ACKNOWLEDGMENTS

I wish to thank my committee James Burchfield, Jill Belsky, Richard Barrett, Mike Patterson, Dan Pletscher, Jon Graham, and David Mattson. Very special thanks to Jim and Jill who always supported my decisions as this research unfolded. I am particularly thankful to Jon Graham and Dave Mattson who have spent countless hours teaching me much about statistics, grizzly bears, and methods. I give special thanks to Michael Madel. Your support and willingness to share data made a large portion of this research possible--thank you for the many hours you spent assisting me. I thank all of the ranchers, managers, and landowners in the Teton for your time and willingness to share information on your livelihoods. Thanks for your support and good laughs, Lloyd and Brenda. Thanks to Justin Grohs, “Buzzi” Breen, Sam Rose, Alan and Starla Rollo, Clay Crawford, and the Teton River Watershed Group for all your help over the years. Thanks to Greg Neudecker, ranchers, and landowners in the Blackfoot Valley for help with pretests. I am grateful for financial support from the University of Montana’s School of Forestry, NSF EPSCOR, Bolle Center for People and Forests, Wilburforce Foundation, Pumpkin Hill Foundation, the National Fish and Wildlife Foundation, LaSalle Adams Fund, the Bunting Family, and MT Dept. of Fish, Wildlife and Parks. I thank Caroline Tan, American Wildlands, Predator Con. Alliance, Minette Johnson, Steve Primm, Tim Clark, Phil Peabody, Deb Peabody, Marc Jones, Mel, and Chris and Rebekah Bunting, for all your support in its many forms. I want to thank Glenn Harris for his inspiration. Your teachings helped get me here. Jim Berkey deserves special thanks for his unflagging GIS tech. support. I am most grateful to my families for their support. Jenny, thank you for your love, devotion, and belief in me. Zoë, you are my hope and light.

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CHAPTER 1: INTRODUCTION

BACKGROUND TO THE PROBLEM

The long term conservation of grizzly bears (*Ursus arctos*) in the United States is largely contingent upon human tolerance. Human caused mortality is a leading factor that inhibits long-term population persistence for grizzly bears (Mattson et al. 1996). Additionally, grizzly bear mortality tends to be spatially concentrated on the periphery of occupied grizzly bear habitat in the United States (US Fish and Wildlife Service, 2003). For example, in the Greater Yellowstone Ecosystem, grizzly bear mortalities were concentrated on peripheral habitat and were associated with the increased frequency of contact with human activities particularly during seasonal variations in key natural bear food supplies (Pease and Mattson, 1999; Mattson et al. 1992). The lands that make up the periphery of core grizzly bear habitats are largely low elevation private lands (Servheen, 1998). In the western United States, these areas are typically privately owned or leased agricultural parcels. Private lands have a variety of anthropogenic food sources and land use practices that can lead to human-grizzly bear conflicts and eventual grizzly bear deaths through management removals (Mace and Waller, 1998).

Historic settlement patterns of early ranchers in creek and river bottoms and subsequent private ownership of these lands has had important consequences for grizzly bears who depend on these same riparian habitats for seasonal life history needs particularly in portions of Montana and Wyoming. The midwestern style of ranching that emphasized winter-feeding, centralized operations, irrigated hay production, quality breeds, and herd docility laid the foundations for contemporary cow/calf operations that dominate land use in many places in Montana, Idaho, and Wyoming (Jordan, 1993).

Moreover, current livestock management practices of seasonally fixed calving periods, routinely used calving areas, and the practice of dumping dead livestock into spatially fixed bone yards (carcass dumps) have contributed to extensive livestock-grizzly bear conflicts in parts of Montana and Wyoming.

The spatial and temporal aspects of human-bear interactions on private lands in a particular ecological context and the social factors like human behaviors and land use practices are important factors to consider within the context of population viability and conflict and mortality risks for grizzly bears. This research examines the factors that predispose grizzly bears to risk of conflicts on private agricultural lands. Specifically, I examine distinct patterns of conflicts that are related to landscape features and spatial and temporal variation of human based agricultural attractants. Throughout this work I use the term “landscape features” to refer to coarse scale vegetation (riparian and wetland) and rivers and creeks. I also use the term “attractants” to denote types of livestock (cattle and sheep), livestock pasture locations, bone yards (carcass dumps), and or beehives. “Conflicts” or “human-grizzly bear conflicts” refer to any incident between humans and bears that have been reported to MT Department of Fish, Wildlife and Parks (MFWP). MFWP has shared a portion of their database on conflicts for this research project.

RESEARCH GOALS

The goal of this research is to examine the spatial associations among landscape features, agricultural attractants, and human-grizzly bear conflicts on privately owned agricultural lands along a portion of north-central Montana’s “Rocky Mountain Front.” The long term population viability for grizzly bears in the United States will, in part, depend on understanding factors that lead to eventual grizzly bear deaths. There are clear

gaps in the literature regarding the explicit spatial and temporal factors on private agricultural lands that lead to repeated conflicts among humans and grizzly bears. There is a limited understanding about the scale at which human grizzly bear conflicts occur or what biophysical features of a landscape are associated with conflict locations.

Moreover, there has been little exploratory analysis that has attempted to control for the effects of biophysical features in a landscape and evaluate the relative contribution that attractants such as livestock type, livestock pasturing locations, bone yard locations, or beehive locations may have on the likelihood of conflicts at seasonal and annual scales.

As localized populations of grizzlies in Yellowstone and Glacier National parks show signs of expansion and recolonization of former habitats, human-bear conflicts will continue to occur on privately owned agricultural lands adjacent to core grizzly bear habitats (Schwartz et al, 2003; Jonkel, 2002). Research that addresses this complex process may help minimize and prevent conflicts and eventual mortalities for grizzly bears in the future by predicting where the spatial locations of future conflicts sites may occur and what types of attractants elevate the risk of conflict for grizzly bears.

This research may provide new information for understanding threatened and endangered species conservation on private lands and emerging habitat conservation planning under the Endangered Species Act. An in-depth study of the people who live with grizzly bears and how their land use decisions and management practices affect grizzly bears will enhance grizzly bear management, and provide preventative management recommendations. Finally, by focusing directly on human-grizzly bear conflicts on private agricultural lands, this work should provide the wildlife management

community with tangible and quantifiable results that may help improve existing programs that seek to minimize and prevent conflicts among humans and grizzly bears.

RESEARCH QUESTION

The research question that guides this work is the following:

What factors predispose grizzly bears to risk of conflict with human activities on privately owned and managed agricultural lands on the Rocky Mountain Front, MT?

The factors that may predispose grizzly bear to risk of conflict on privately owned agricultural lands are varied and complex. Human attitudes towards bears, historic ranching settlement patterns, current land uses, road densities, human access, recreation, grizzly bear behavior, municipal and household garbage management, and variation in ecological conditions all influence the frequency and severity of human-grizzly bear conflicts. It is beyond the scope of this research to address all of the factors that lead to human-grizzly bear conflicts. However, I have identified the specific factors for analysis based on the social and ecological context of the study area region and on my understanding of contemporary human-grizzly bear conflicts based on my own 1999 pilot study, existing data sets on reported human-grizzly bear conflicts, and extensive review of wildlife management reports, management plans, and existing literature.

Since this work is set in an agricultural landscape that is dominated by livestock and honey production and more than half of reported human-grizzly bear conflicts have been associated with these practices, I have focused this exploratory analysis on understanding how locations of cattle and sheep pastures, bone yards, and beekeeping management practices and present ecological conditions affect the likelihood of human-grizzly bear conflicts (Madel, 1996). There have been few works that integrate both

social and ecological factors for understanding human-grizzly bear conflicts, particularly on private lands that are adjacent to populations of grizzly bears. With the exception of a handful of studies, research on private landowners and grizzly bears has tended to focus on attitudes or perceptions rather than interactions or how specific human behaviors or land use practices impact bears. Additionally, there has been little attention given to historic ranching settlement patterns or the specific styles of livestock management that may contribute to conflicts.

In Chapter 4, I discuss the spatial context of human-grizzly bear conflicts with respect to historic ranching settlement patterns and current livestock and beehive related management practices. This chapter provides an important historical backdrop that elucidates how ranching settlement, animal husbandry style, and current land use management have resulted in both spatial and temporal patterns that appear to be related to human-grizzly bear conflicts.

In Chapter 6, I identify the types of landscape features and attractants that are present at conflict sites and I discuss how these factors affect the probability of conflict. Chapter 6 is largely a descriptive analysis relying on Geographic Information System (GIS) mapping and univariate statistical tests that lay the foundations for understanding the landscape features and attractants that are associated with distinct concentrations of conflicts or what I term “conflict hotspots.” This analysis explores and identifies individual factors or candidate variables that were later included in a modeling effort in Chapter 7. To this end, Chapters 6 and 7 are sequentially and conceptually linked. In many respects, the detailed results found in Chapter 6 provide an opportunity in Chapter 7 for model testing and validation. Chapter 7 is the logical culmination of this geospatial

analysis and addresses relative importance of multiple factors isolated in Chapter 6 on conflict likelihood through multivariate regression modeling.

STRUCTURE OF THE THESIS

This thesis is structured to have three chapters serve as independent research articles (Chapters 5, 6, and 7). Thus, there is some inherent redundancy with respect to introductions and methods in these chapters. In each of the article chapters, I have provided summary conclusions but not management recommendations. These can be found in Chapter 8, in addition to overall conclusions. I chose this format so that a reader who skips some chapters can still find the key conclusions and management recommendations in a discrete section. Nevertheless, this thesis is sequentially organized such that each chapter builds off the previous one. Chapters 1, 2, 3, and 4 provide the reader with an introduction to the problem, a literature review, the research approach and overview of methods, and a chapter on the historic and current context of livestock and honey production in the study area. These four chapters are meant to serve the reader with a succinct and logical background to each of the independent research article chapters. I conclude the thesis with Chapter 8 where I discuss key findings, provide management recommendations, and acknowledge the limitations of the study. In the following paragraphs, I briefly discuss the content and logic of Chapters 2 through 8.

In Chapter 2, I provide a literature review that justifies the relevance of this research within the larger body of work on grizzly bear conservation in North America. The literature review is not meant to be exhaustive and I have attempted to provide a brief chronological overview of the salient early works ranging from roughly the 1950s to the present. I then focus on pertinent literature that guides my work with respect to

research on grizzly bears and private lands. I have organized these works into the following categories: Mortality Risks, Human-Grizzly Bear Interactions on Private Lands, Grizzly-Bear-Livestock Conflict Research, and Landscape Scale Work on Private Lands. I demonstrate how each of these categories of scholarship has relevance to my research and I illustrate how my work fills needed gaps in this body of knowledge.

In Chapter 3, I discuss the integrative nature of this research and summarize the key methods used for the independent research article chapters. Specifically, I justify using an integrative research approach that relies on methods from both the natural and social sciences. I discuss the use of GIS as an appropriate tool to facilitate integrative research for data collection, data display, and data analysis. I then provide an overview of all methods used in the thesis with specific references to chapters that cover further methodological detail.

Chapter 4 introduces the reader to the historic and current context of land uses in the study area. This chapter includes a description of the study area region with an emphasis on ownership patterns, a brief history of the development of the livestock industry, and the current spatial and temporal aspects of livestock and beehive management in the study area.

Chapter 5 discusses how an interactive mapping technique was used for data collection and how the use of digital imagery in a mapping context can produce high quality data with livestock related land users. This chapter is largely a methodological or “techniques” paper that provides the reader with the specific methods for GIS based mapping and discusses the generation of data with participants in this study. All data on

livestock and beehive management practices that were co-produced with participants were used for analysis purposes in Chapters 6 and 7.

In Chapter 6, I offer a spatial analysis of human-grizzly bear conflicts on private lands providing evidence that specific types of attractant sources are associated with chronic problem areas, or what I have termed conflict hotspots. As was stated previously, this chapter is largely an exploratory analysis that relies on a variety of univariate statistical tests to evaluate the possible associations among agricultural activities, ecological conditions, and human-grizzly bear conflicts.

Chapter 7 is an extension of Chapter 6 that builds on the univariate test results found therein and provides a logistic regression modeling analysis that simultaneously examines multiple factors that contribute to the likelihood of human-grizzly bear conflicts. I have constructed three seasonal models and one annual model that accounts for seasonality and predicts annual or overall conflict likelihood.

The final chapter (Chapter 8) provides key findings from the study and management recommendations. I also discuss how the methods of interactive mapping (Chapter 5) can be incorporated into existing wildlife management plans. I discuss limitations of this study, future research needs, and I end with my own concluding remarks.

CHAPTER 2: LITERATURE REVIEW ON HUMAN-GRIZZLY BEAR INTERACTIONS

INTRODUCTION

An abundance of literature on the biology, conservation, and management of grizzly bears in North America has been generated by scores of researchers from academia, government agencies, independent scientists, and conservation groups. However, for this dissertation, my intent is to provide a brief overview of the broad trends that characterize grizzly bear research in North America. This is found in the section titled, “Early Work.” I then discuss in greater detail, the pertinent works that are related to this research. I have grouped this body of literature into the following sections: Mortality Risks, Human-Grizzly Bear Interactions on Private Lands, Grizzly bear-livestock Conflict Research, and Landscape Scale Work on Private Lands and Grizzly Bears. Based upon this large body of work, it appears mortality risks that grizzly bears face are primarily located on the periphery of their core habitats in North America. In the western United States, these peripheral habitats are generally lower in elevation and are under private ownership. The literature suggests that grizzly bears face increased risk of conflicts, management relocations, and eventual mortalities due to the abundance of anthropogenic food sources and attractants that are often located on private lands.

EARLY WORK

Early research on grizzlies focused on bear biology, emphasizing general ecology of the species and life history requirements (Hornocker, 1962; Murie, 1981). Some of this early work was conducted by pioneering scientists like the Craighead brothers whose radio-tracking techniques were used extensively in future wildlife research throughout the world (Craighead and Craighead, 1965). The Craigheads studied grizzly bear behavior,

reproductive biology, and demography in Alaska and extensively in Yellowstone National Park for more than two decades and focused public attention to human-grizzly bear conflicts regarding unsecured human garbage in Yellowstone National Park (Craighead and Craighead, 1972; Craighead, 1977; Craighead et al., 1995). By the 1970s and 1980s, declines in grizzly bear populations in the United States would fuel research that examined habitat decline, habitat use, population dynamics, and human impacts to bears (Jonkel et al. 1979; Mace and Jonkel, 1983; Schallenberger and Jonkel, 1980; Kendall, 1983; Shaffer, 1983; Knight and Eberhardt, 1987; Herrero, 1976; Herrero, 1985). Throughout the 1980s and 1990s, research continued to focus on habitat decline, road impacts, population dynamics, mortality risks, and the policy aspects of grizzly bear conservation and management in North America (Mattson, 1990, Kasworm and Manly 1990; Boyce, 1995, Mattson et al., 1996, Clark et al., 1994). In 1987, a major review of grizzly bear literature sponsored by the Interagency Grizzly Bear Committee documented some 1,284 contributions to the field (Harting, 1987). More than half of this compendium is dedicated to literature on human impacts, management techniques, and management strategies for grizzly bears. The volume and type of research found in the compendium reflects, in part, a response by researchers, managers, and conservationists to extractive uses of public lands during the 1970s and 1980s and management agency requirements to comply with the Endangered Species Act under that listed grizzly bears as a threatened species in 1975. For example, many studies focused on the impacts of oil and gas exploration/development, road building, timber harvesting, and livestock grazing on US National Forests and Bureau of Land Management lands as well as work on the increased recreational impacts to bears on public lands.

As the fields of conservation biology, landscape ecology, and population genetics burgeoned during the 1990s, many researchers focused on questions regarding population viability, risks and causes of mortality, sizes of habitats, vulnerability of genetically isolated populations, and landscape level conservation planning (Mattson, 1998; Wright, 1996; Mattson et al. 1996, Allendorf, 1997, Noss et al. 1996; Carroll et al. 2001). Human-grizzly bear interactions and subsequent conflicts and mortality risks were one of the key findings that emerged from work done in the early and mid-1990s.

MORTALITY RISKS

The decline of grizzly bear populations in the United States and the southern Canadian Rockies is clearly linked to human causes, as human-grizzly bear conflicts are often a precursor to mortality. Mattson et al., (1996:134) suggested that, "There is little doubt that the current persistence of grizzly bears at lower latitudes is largely determined by human predation, modified by the effects of food abundance on recruitment." A synthesis of long-term grizzly bear radio collar studies in southern Canada and the United States found that from 1974 to 1996, 85% of known bear mortality was attributed to humans (Mattson et al. 1996). McLellan et al. (1999) found that undetected grizzly bear deaths were typically due to nonhunting human causes in the US and southern Canada and that from 1975-1997, malicious killing was the major cause of grizzly bear death in Montana. Grizzly bear mortality in the US tends to be spatially concentrated on the periphery of core habitats, particularly in portions of Montana (U.S. Fish and Wildlife Service, 2003). Core habitats refer to lands that contain self-sustaining populations of grizzly bears. These are generally a mix of multiple use national forest lands, national parks, and designated wilderness areas.

In Yellowstone National Park variation in seasonal food production of whitebark pine seed (*Pinus albicaulis*) was correlated with grizzly bear mortality. Grizzly bear deaths nearly doubled during years when white bark pine seed crops failed, causing bears to forage in lower elevations that are often dominated by human uses and contain attractants that can lead to an increased frequency of contact with humans, conflicts, and eventual mortality (Pease and Mattson, 1999). These less secure, low elevation habitats are typically privately owned agricultural lands, contain a variety of unnatural bear foods, and are of importance for research and conservation efforts (Servheen, 1998). In Montana, researchers have called for a reduction in the availability of anthropogenic food sources and attractants on privately owned lands to reduce conflicts and mortalities particularly for female grizzly bears (Mace and Waller, 1998).

HUMAN-GRIZZLY BEAR INTERACTIONS ON PRIVATE LANDS

The use of privately owned habitat by grizzly bears and the nature of the associated interactions play a role in where bears can thrive and where they can not (Servheen, 1989). Human-bear interactions are in part responsible for what habitats grizzly bears use. The type of habitat or constituents that define effective habitat are highly relevant. Craighead et al. (1995) suggested that food, cover, denning habitat, isolation, and space are important for defining effective grizzly bear habitat. Nonetheless, human activities have greatly modified these elements throughout historic ranges of grizzly bears. Human behavior and associated impacts on bears and bear habitat are the limiting factor inhibiting increases in bear populations and habitat expansion in the United States.

Montana Department of Fish, Wildlife, and Parks biologists Keith Aune and Wayne Kasworm spent considerable time observing and researching grizzly bears on Montana's Rocky Mountain Front. They have suggested that:

The distribution of grizzly bears may be a function of where bears are allowed to live as much as an actual preference for habitat. Bears in the Teton area are apparently able to exploit more lowland country than bears to the north or south, although suitable lowland habitat occurs in these other regions (Aune and Kasworm 1989:119).

Aune and Kasworm imply that human tolerance for grizzly bears is a key component for determining what types of habitats grizzly bears can actually use. Thus, specific human behaviors and land uses on private lands appear to be important factors that affect population viability and conflict and mortality risks for grizzly bears.

Previous social science research on human perceptions of grizzly bears has focused on cultural aspects, public attitudes, and policy implications of perceptions of grizzly bears at national scales (Kellert, 1985a; Kellert, 1985b; Kellert, 1992; Kellert et al. 1996). Work at the regional level by Frost (1985) found that a majority of residents from a survey sample in the Mission Valley of western Montana had favorable attitudes towards bears. An informal survey by Perry (1977) also found positive attitudes of Montana North Fork (Flathead) Valley residents towards grizzly bears.

Other work on human perceptions of grizzly bears has focused on attitudinal surveys in Canadian and US National Parks. These works tend to emphasize public attitudes towards bears, knowledge about appropriate visitor behavior, knowledge about the hazards of recreating in bear habitat, and injuries to humans from bears (Marsh, 1972; Bryan and Jansson, 1973; Freeman-Haet, 1973; Fortier, 1983; Sundstrom, 1985; Herrero and Fleck, 1990). Many of these studies have been applied toward educational outreach and park management in North America. Other studies have focused on human impacts

to bear behavior and bear habitat in and around national parks in the US and Canada (Gunther, 1990; McLellan, 1990; Gibeau et al. 2002).

The existing work on grizzly bear conservation on private lands in the United States has generally been in the form of university based research, environmental impact statements; Montana, Wyoming, Idaho, and Washington wildlife agency reports; Interagency Grizzly Bear Study Team Reports; and a handful of peer-reviewed journal articles. These studies have focused on the impacts of habitat disturbance for bears, linkage zones, local community attitudes, and livestock management issues. Moreover, the impetus for much of this work was due to management actions on public lands that are near privately owned lands. Consequently, some research has investigated the public/private conservation issues involving grizzly bears, yet little work has explicitly been directed toward understanding the spatially explicit conditions of livestock and beekeeping practices on private lands.

The Border Grizzly Project, initiated by researchers at the University of Montana in the 1970s provided some of the first radio telemetry data on habitat use by grizzly bears on private lands along the Rocky Mountain Front in Montana. In addition to providing much understanding of bear biology, these researchers found that low elevation riparian areas were seasonally important for bears (Schallenberger and Jonkel, 1980).

By the 1980s oil and gas exploration efforts on USFS, BLM, and private lands throughout the Rocky Mountain Front region triggered a series of Environmental Impact Statements (EIS) and agency reports by the Montana Department of Fish, Wildlife and Parks that addressed the impacts of oil extraction on grizzly bear habitat, behavior, and population dynamics (Aune and Kasworm, 1989). These studies contributed valuable

information mainly on habitat use by bears, home range sizes, feeding habits, and implications for bear management. Both the environmental impact statements and the state of Montana reports from this period call for a better understanding of human perceptions and the nature of human interactions with bears. This is also reflected in the current reports of Montana Department of Fish, Wildlife, and Parks (Madel, 1996). Additionally, management recommendations from top-level bear managers have suggested that local input from private landowners and communities is important for developing tolerance for grizzly bears. These recommendations also stress the need to enhance conservation easement procurement and coordination with state and not-for-profit land trusts (Servheen, 1989; Servheen, 1998).

GRIZZLY BEAR-LIVESTOCK CONFLICT RESEARCH

Other literature that addresses human-bear interactions on privately owned or publicly leased lands focuses on livestock-predator conflicts and prevention techniques for minimizing conflicts with grizzly bears and European brown bears for residents and livestock producers (Kaczensky, 1999; Bromley, 1989; Green and Woodruff, 1989; Gray and Sutherland, 1989; Sillero-Zubiri and Laurenson, 2001; Stivers and Irby, 1997). A recent publication by long-time wolf researcher, L. David Mech and colleagues (2000) assessed factors that may predispose Minnesota farms to wolf depredations on cattle. These researchers found that differences between farms with chronic livestock losses to wolves compared to matching farms located nearby without losses were a result of the size of operation, number of cattle, and the further stock were from human dwellings. However, the researchers acknowledged that farm size by itself may have been a neutral factor and that other unknown factors may play a role in why larger farms apparently

suffer more livestock losses from wolves than do smaller operations. This is one of the few studies to date that systematically addressed human-predator conflicts on private agricultural lands particularly with a spatial component.

Stivers and Irby's (1997) study on the Rocky Mountain Front involving livestock grazing in mesic grizzly bear habitat showed that grizzly bears and livestock compete for similar plant foods. These scientists also found that deferred grazing in pastures with willow and aspen stands allowed more plant generation for bears. And, removing cattle from riparian pastures prior to having 50% of the herbaceous material grazed off, minimized impacts on seasonally important bear foods. These authors did not discuss the potential conflict situations that result as the frequency of contact among grizzlies and cattle is magnified in riparian habitats.

Recent work by Sillero-Zubiri and Laurenson (2001) has documented successful prevention and deterrent techniques such as fencing for protecting livestock in rural areas. In practice, much of these techniques and documentation has been carried out wildlife managers in the field and complemented by local residents' own practical adaptations. The use of livestock guarding dogs and electric fencing of livestock to deter grizzly bears has shown success in Scandinavia, the US Northern Rockies, and Alaska (Hansen and Bakken, 1999; Hansen and Smith, 1999; Madel, 1996; Follmann and Hechtel, 1990). Other researchers have called for a return to intensive traditional European and Eurasian herding practices that dominated much of European animal husbandry until the past century (Breitenmoser, 1998) coupled with a zoning approach to minimize conflicts (Sagør et al. 1997). While largely untested, these approaches may

have relevance for livestock management practices on both public and private lands in the western United States.

LANDSCAPE SCALE WORK ON GRIZZLY BEARS AND PRIVATE LANDS

Other researchers have studied grizzly bears and private lands indirectly through landscape level modeling efforts that focus on connectivity among sub-populations. These studies have largely been GIS models (Servheen and Sandstrom, 1993; Boone and Hunter, 1996; Walker and Craighead, 1997). While these models offer guidance about the risk of different travel routes for grizzly bears based on a variety of defined parameters, for example, road and dwelling densities, these studies have not addressed the complex issues of how people live and make a living in grizzly bear habitat nor do these studies attempt to model specific human behaviors that impact grizzly bears. Apparently the linkage zone model that is currently being developed by the US Fish and Wildlife Service under the grizzly bear recovery plan is planning to incorporate some limited social science inquiry in areas identified as possible linkage zones (Parker and Parker, 2002). In the Swan Valley of Montana, past work by the US Fish and Wildlife Service and local residents on private lands incorporated road closures to enhance grizzly bear security, private corporate timber management impacts on bears, grazing impacts on bears, and securing household garbage from grizzly bears in linkage zones (Pelletier, 1995).

Other recent modeling literature related to grizzly bears and private lands include spatial approaches for predictive habitat models, defining habitats suitable for restoration of grizzly bears, and multi-focal species models for landscape level conservation planning (Mace et al. 1999; Merrill et al. 1999; Carroll et al. 2001; Mattson and Merrill;

2003; Singleton, 2003). These models offer quantified means to prioritize and identify critical habitats that cross both public and private ownership jurisdictions. It is clear from the modeling literature that private lands are a key component for seasonal habitat needs of grizzly bears and for possible dispersal routes among isolated populations. These models have typically relied on GIS based data sets involving road densities, satellite vegetative data, ownership data, bear food availability data, and habitat distribution data for a variety of predator species. The intent of these model approaches is typically to identify key habitats and possible areas for recovery for species like grizzly bears rather than detail specific conditions on private lands that may pose conflict and mortality risks to grizzlies.

Many current and on-the-ground applications of large scale modeling approaches to wildlife habitat connectivity for grizzly bears in the US can be found on the Internet. For example, researchers from the U.S. Forest Service have identified key linkage areas for carnivore habitat connectivity based on the habitat needs of a suite of carnivore species and the existing road and highway networks in Montana, Idaho, and Wyoming. This effort focused on identification of the possible landscape linkages rather than prescribing any specific conservation solutions on the ground (Reudiger et al. 2002). However, these researchers suggest that local solutions will be needed across the larger landscape.

Two Montana conservation groups, American Wildlands (2003) and the Craighead Environmental Research Institute (2003), are actively involved with carnivore linkage work in the Northern Rockies. They have collaborated for several years on connectivity modeling and analysis in several different geographic areas in Montana,

Idaho, and Wyoming and are implementing on-the-ground projects in several areas on private lands. For example, in the Bozeman Pass area, American Wildlands has formed a working group and is coordinating with Montana Department of Transportation, county planners, land trusts, Montana Fish, Wildlife and Parks biologists, Forest Service engineers and biologists, and Western Transportation Institute to make recommendations for highway mitigation and conservation on private lands. One of American Wildland's strategies has been to partner with local land trusts and alert these groups to the specific private lands that are in the linkage areas that have been identified in their model analysis (American Wildlands, 2003). In all of these current efforts, it is evident that private lands are integral for large, landscape scale connectivity for species with wide-ranging habitat needs like grizzly bears.

CHAPTER 3: RESEARCH APPROACH AND OVERVIEW OF METHODS

INTRODUCTION

This chapter contains two major parts: the first describes the integrative nature of this research and the second provides an overview of the specific methods that were used. I have organized the methodological overview into discrete sections that contain specific references to individual chapters where the reader can find detailed methodology. This overview is not meant to be exhaustive, but provides enough detail to tie the methods together as a whole.

RESEARCH APPROACH

The study of large carnivore recovery in the United States is contextually dependent on ecological and sociological factors that vary by species, across ecosystems and time (Clark et al., 1994; Clark et al., 2000; Clark, 2002). As such, I used an integrative, case study approach that relies on multiple methods from both the natural and social sciences (Yin, 1989). Tenets from the field of conservation biology also guide but do not limit this work in that I have attempted to break down traditional distinctions of “pure” versus “applied” science as I seek to integrate scientific understanding with practical management applications for current conservation problems. Additionally, the questions that frame this research reflect a biocentric philosophy—that the diversity of all life at all levels, including grizzly bears, is inherently valuable. Moreover, I focus on factors that pose lethal risks to grizzly bears because human caused mortality is considered a major limiting factor to long-term population viability. This work also reflects interdisciplinary and integrative thinking that links both social and ecological

phenomena and strives to produce practical results that can benefit both grizzly bears and those who live with them (Meffe and Carroll, 1997).

My position is that complex phenomena like human-grizzly bear conflicts that occur at different spatial and temporal scales should be studied contextually. In other words, humans are part of the ecosystem and there are reciprocal interactions that occur as humans shape their unique environments over time and are in turn shaped by it (Bell, 1998). Perhaps most importantly and despite the inherent complexity, I am interested in the study of human behaviors and management practices that are a product of the context in which humans and wildlife coexist (Yin, 1989). Thus, I have attempted to account for both the ecological and social factors that predispose grizzly bears to risk of conflicts. Specifically, I focus on three units of analysis. These include: 1) Historic and current livestock management and beekeeping practices that influence the likelihood of conflicts with an emphasis on the geographic distribution of livestock pastures, bone yards, and beehives and the seasonal and annual variation of these activities, 2) Ecological features of the landscape that provide habitat to grizzly bears, and 3) The spatial and seasonal distribution of reported and verified grizzly bear-human conflicts within a defined study area. One of the greatest challenges of integrating and analyzing data at nested scales (spatial and temporal) is a matter of organization. Fortunately, today's geographical, statistical, and database software is capable of displaying, organizing, and analyzing datasets that would have been impractical to attempt even a decade ago.

Geographic Information Systems as a Tool for Integrative Research

The multiple scales of analysis that I use have complex spatial and temporal components and while there are certainly advantages to studying these separately, I

contend that insights are more readily developed when both ecological and social factors are taken into account simultaneously, particularly over time. Geographic Information Systems (GIS) are a particularly appropriate tool for generating these types of insights (Liverman et al., 1998). At a recent workshop held in Florida to identify global research priorities, the use of satellite and aerial photography in conservation research efforts was identified as a pressing need (Soulé and Orians, 2001). I have relied on both throughout my work at various stages and I used GIS for data collection, organization, display, and for extensive geostatistical analysis. Geographic information systems are techniques for organizing and viewing these types of data and can help in identifying patterns in complex phenomena that vary across space and time. This process of data reduction into a visual display is perhaps one of the greatest strengths of GIS.

Moreover, GIS is said to be “data driven” in that visual or graphical data are supported or “backed” by quantitative or descriptive textual data. For example, data that have been shared by Montana Fish, Wildlife and Parks for this research have been of this nature. Their database on reported and verified grizzly bear conflicts contain information on the locations, dates, types, outcomes, and when available, the sex and age classes of grizzly bears involved in conflicts on private lands. These data fields can be compared to human based activities such as seasonal variation in animal husbandry practices like calving. One then has the ability to ask questions about the seasonal and spatial distribution of livestock management practices at micro and meso-scales and how these might contribute to the likelihood of conflicts (see for example, Chapters 6 and 7). Throughout this research, I have used GIS applications extensively for data collection, data analysis, and for display of both ecological and social information. It has been a

vital tool for linking information and for pursuing an integrative research approach. In the following sections, I provide a methodological overview for the choice of study site, the selection of participants, primary data collection methods, sources of data, and data analysis.

OVERVIEW OF METHODS

Study Site Selection

The U.S. Fish and Wildlife Service (1993) suggest that the grasslands of north-central Montana's Rocky Mountain Front (RMF) region may be the only place in the lower 48 states where grizzly bears have continuously occupied their former prairie habitat (Figure 3.1). This narrow band of foothill prairie grassland, or ecotone, contains a rich mosaic of habitat types and grizzly bears are seasonally dependent on lower elevation lands that are typically in private ownership or leased for agricultural or grazing purposes. I chose this study site due to its importance to grizzly bears and for the fact that private ranchers own extensive portions of this same habitat. This is a unique place to study the interactions and subsequent conflicts that people have with bears in an agricultural setting.

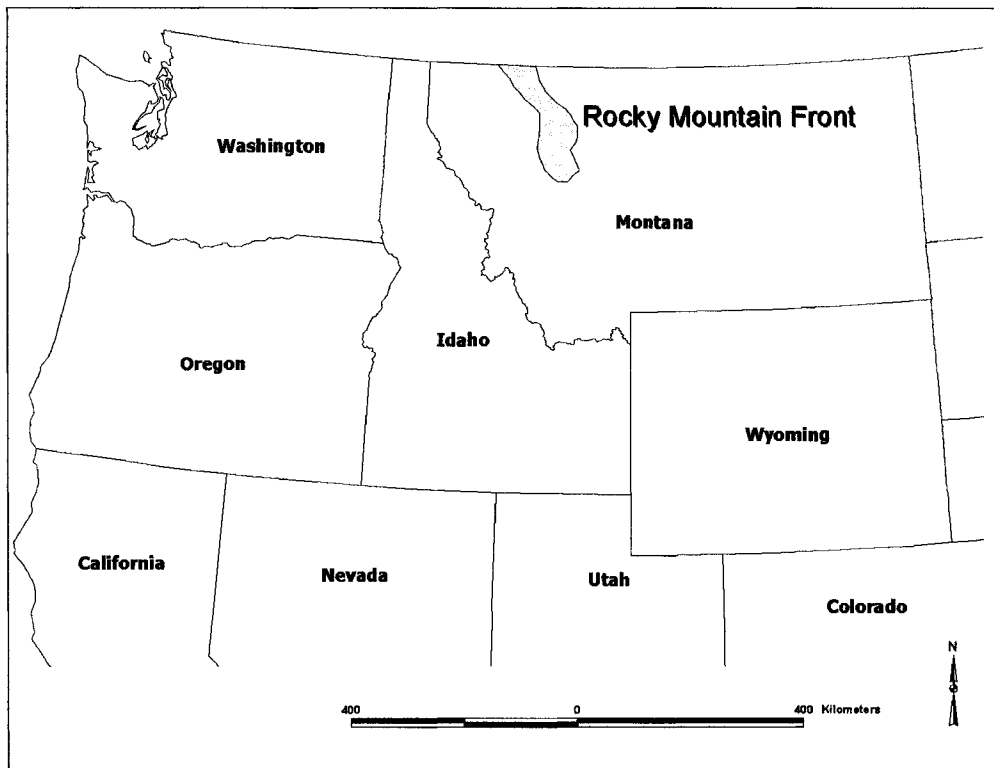


Figure 3.1. Location of north-central Montana’s Rocky Mountain Front

Aune and Kasworm (1989) found along the Rocky Mountain Front that approximately 80% of grizzly bear spring habitat was found on private lands with less than 5% slopes and were primarily fens and riparian communities. The riparian areas used by bears provided important foraging opportunities, cover, and secure habitats for movement (Aune and Kasworm, 1989). The researchers also found that “low-land bears” moved from their denning habitat on the national forest to low elevation habitats in riparian areas until the pre-denning and denning periods. “Backcountry bears” used the privately owned riparian habitat during the spring and returned to higher elevations during the summer and fall. Grizzly bears in the Teton River area showed a higher fidelity to riparian lowlands than did bears in the watersheds to the north (Badger-Two Medicine area) and south (Sun River areas). This is consistent with observations by Madel (M.J. Madel, personal communication, January 10, 2003) who has found that

females with cubs often have overlapping home ranges on low elevation private lands, spend extensive periods of each year on private agricultural land, and that grizzly bear densities were seasonally highest in the upper Teton watershed.

These same private lands have also been used for ranching, agricultural, and honey production since the late 1800s. After preliminary site visits and reviews of literature on research and management of grizzly bears for the United States, it was evident that the RMF region would be a good place to study human-grizzly bear conflicts. The upper Teton River Watershed delineates the study area. I bounded the study area on the west using the Lewis and Clark National Forest boundary and on the east using the rough transition of cattle ranches to intensive winter wheat farms. The north and south boundaries of the study area were based on the Teton River watershed. The study area is approximately 172,000 hectares (Figure 3.2).

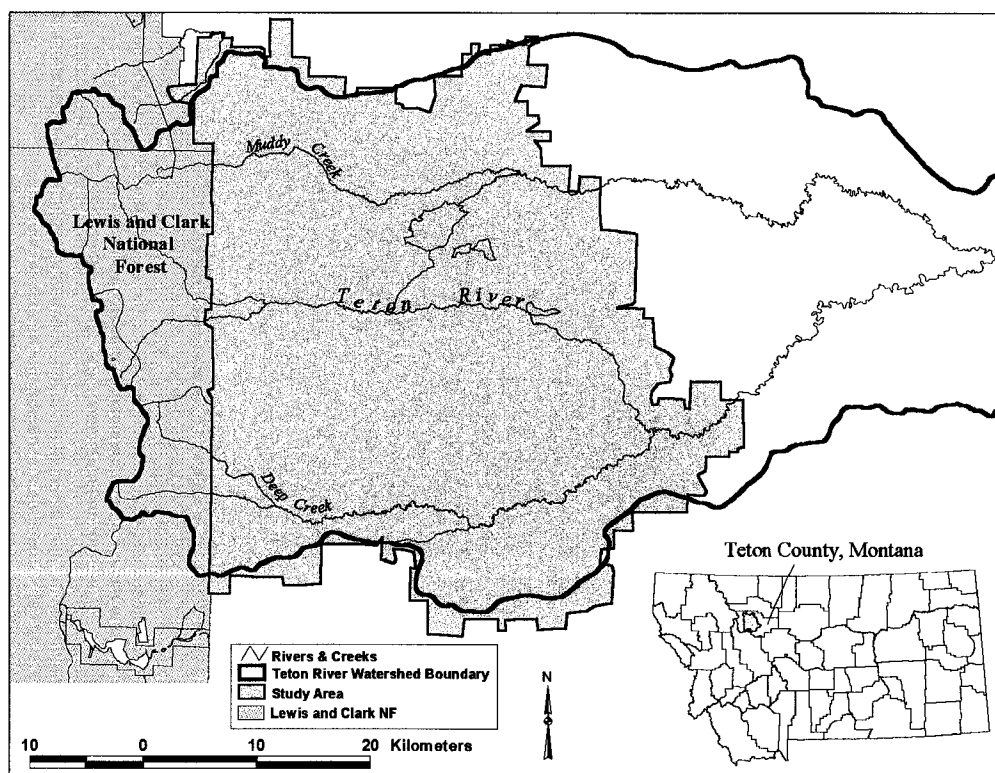


Figure 3.2. Study area location in North-central Montana.

Selection of Participants

There were 64 total livestock related land users in the study area. I conducted a census and collected information from 61 of these land users during personal interviews (95% response rate). The category “livestock related land user” included: cattle and sheep ranchers, outfitters, guest ranchers, hobby ranchers, and a honey producer. I developed these categories using the databases and assistance of the Teton County Agricultural Extension Service to arrive at a study area population of 64 active livestock related land users. Additionally, the State of Montana classifies bees as “livestock” so I included honey producers in the definition of these livestock related land user categories. I justified a census of livestock related land users since 90% of reported human-grizzly bear conflicts documented by Montana Department of Fish, Wildlife and Parks from 1986-2001 were associated with livestock related land users as defined above. Seventeen percent (17%) of reported human-grizzly bear conflicts from this same period were associated with beehives managed by the local honey producer and 73% were associated with cattle and sheep ranchers, outfitters, guest ranchers, and hobby ranchers. The 61 livestock related land users that were surveyed either own, manage, or lease approximately 130,733 hectares in the study area. The total study area population of 64 active livestock related land users accounted for 134,048 hectares of the study area. Approximately 97% of the land base in the study area under livestock related land use was covered by the census. I systematically identified all grazing and agricultural lessees of state school trust parcels in the study area using the Montana Department of Natural Resources and Conservation databases. This enabled me to account for both private and leased land under management of the livestock related land users.

Data Collection Methods

I conducted in-depth personal interviews with all livestock related land users ($n=61$). Participants were initially contacted with a letter of explanation and I followed up with a telephone call to schedule interviews. I recorded information regarding livestock management practices, beehive locations, and beehive protection status with a standard questionnaire and with a laptop computer using a technique I call interactive mapping. See Chapter 5 for a complete discussion.

I used interactive mapping to collect specific spatial and temporal information regarding livestock and beehive management practices from 1986-2001 that I felt were key factors that may impact the likelihood of conflicts for grizzly bears. These factors formed the basis for a multitude of statistical tests and modeling efforts found in Chapters 6 and 7. I based my decision to focus on these livestock and beehive practices after extensive review of pertinent literature and a pilot study conducted in 1999. The factors I focused on included: livestock pasture locations and season of use, calving and lambing area locations and season of use, carcass dump (bone yards) locations, livestock densities, and beehive site locations, dates of development, season of use, and protection status (fenced or not fenced). Chapter 5 provides detailed information on data sources and step-by-step methods used for this technique. All questions and computer mapping methods were pre-tested in a different location in Montana so as not to bias participants in the study area. Interviews and mapping sessions were tape recorded and professionally transcribed.

GIS Base layer data and Reported Grizzly Bear Conflict Data

Geographic Information Base layers and reported grizzly bear conflict data were used for geospatial analysis in Chapters 6 and 7. The following sections describe data sources used for the base layers in GIS for hydrography (rivers and creeks), vegetative cover types, and reported human-grizzly bear conflicts. Chapters 5, 6, and 7 have detailed descriptions of the sources, assumptions, and possible error associated with the use of these secondary data sources.

I used a digital vector based hydrography layer at 1:100,000 scale to represent rivers and perennial creeks in the study area for analysis in Chapter 6 and 7 (NRIS, 2001). Metadata records can be obtained at the Montana Natural Resource Information System (NRIS) database (2001). Metadata are systematic records detailing the origin of a particular dataset, data accuracy, and any methods that may have been used to process data for GIS applications. Metadata provide the public with an official and standardized means to evaluate the accuracy of data and ensure that data are used at appropriate scales and for appropriate analysis.

I used a digital, 30-meter Landsat Thematic Mapper (TM) image of the current vegetation map of western Montana (Redmond, 1996) and photo interpretation of digital orthophoto quarter quads (DOQQ) of actual vegetation to delineate riparian and wetland-associated vegetation for analysis in Chapter 6. Digital orthophotos were obtained from the Natural Resource Conservation Service office in Bozeman, Montana. These aerial photographs were created by the United State Geologic Survey throughout the mid 1990s and are high resolution (1 m), 1:24,000-scale (USGS, 2001). I used the same 30-meter landsat imagery to develop 9 distinct land cover types for logistic regression modeling in

Chapter 7. Additionally, I aggregated several grizzly bear management units (BMU) that were adjacent to the study area to act as a surrogate for “core” grizzly bear habitat for a potential explanatory variable in the logistic regression model.

Montana Department of Fish, Wildlife and Parks (MFWP) shared a data set on reported human-grizzly bear conflicts within the study area boundary ($n=178$) from 1986-2001. Human-grizzly bear conflicts cover a spectrum of possible incidents involving livestock depredations, beehive damage, or close proximity conflicts where a grizzly bear may have been near a residence. I use the term “human-grizzly bear conflict” or simply “conflicts” throughout this document as incidents typically have their origin in anthropogenic based attractants or land uses. The database was started in the mid-1980s and MFWP has systematically collected information on reported conflicts to the present. Specific information from the database used in both Chapter 6 and 7 included: 1) calendar date of conflict, 2) Universal Transverse Mercator (UTM) coordinates, 3) type of conflict, and 4) identity of grizzly bear if known.

Data Analysis

In Chapter 5 I described the data sources and techniques used for interactive mapping. I assessed computer and hardware performance in field settings and I used content analysis to measure participants’ reactions to the process of interactive mapping (Babbie, 1989). The content analysis was based on transcribed interview texts from the specific section of the questionnaire that contained the mapping exercise. I specifically focused on verbal reactions that were positive, negative, or neutral. These were summarized and tallied to provide a simple measure of the response that participants had regarding the mapping method.

In Chapter 6 I relied on standard GIS analysis tools and a variety of univariate statistical tests to produce a spatial analysis of factors that put grizzly bears in risk of conflicts with livestock and beekeeping activities. I used ArcView's Spatial Analyst function to produce continuous density surface maps to identify clusters of conflicts and to isolate types of attractants that were found in what I term "conflict hotspots." Once I isolated these factors, I used discrete univariate tests based on random distributions or Monte Carlo (MC) simulations to statistically compare spatial associations of ecological features (rivers and creeks) and management practices to conflict locations versus random distributions. I had to develop specific Arc Macro Language (AML) scripts (computer based language program) to run MC simulations in ArcView. I also used Chi-square tests to determine if there were significant differences in numbers of conflicts at beehives with fences compared to those without fences. Finally, I used Z-tests of proportions to test for significant use (as measured by conflict locations) of riparian and wetland associated vegetation by grizzly bears given this vegetation's availability in the study area.

I used logistic regression modeling in Chapter 7 to evaluate the relative importance of a host of landscape features and attractants on the likelihood of conflict. Initially, I organized the spatial and temporal information on livestock management and beekeeping practices for 1986-2001 in a land use history database in ArcView. I accounted for changes in livestock management and beehive site locations and protection status for each season of each year for the study time frame. I used Akaike Information Criteria (AIC) and Hosmer-Lemeshow goodness-of-fit statistics for model selection purposes. Detailed methodology is found in Chapter 7.

CHAPTER 4: THE GEOGRAPHY OF RANCHING: HISTORICAL IMPLICATIONS FOR UNDERSTANDING THE SPATIAL AND TEMPORAL CONTEXT OF HUMAN-GRIZZLY BEAR CONFLICTS

INTRODUCTION

The contemporary context of human-grizzly bear conflicts on private agricultural lands on the Rocky Mountain Front (RMF) has historical origins that influence the spatial and temporal nature of incidents between human land use activities and grizzly bears. Settlement patterns in creek and river bottoms and subsequent private ownership of these lands has had important consequences for grizzly bears who depend on these same riparian habitats for seasonal life history needs. The midwestern style of ranching that emphasized winter-feeding, centralized operations, irrigated hay production, quality breeds, and herd docility laid the foundations for contemporary cow/calf operations that dominate land use on the RMF. Moreover, today's livestock management practices of seasonally fixed calving periods, routinely used calving areas, and the practice of dumping dead livestock into spatially fixed bone yards (carcass dumps) have contributed to extensive livestock-grizzly bear conflicts.

Additionally, the State of Montana's apiary licensing system that began in the 1940s has resulted in commercial beekeeper "territories." The state requires that beehive site locations be registered to the quarter section and used annually. Each territory is required to be 3 miles from other commercial areas. Individual territories typically have beehives spatially dispersed over large areas depending on local ecological conditions and colony size. Unprotected beehives in occupied grizzly bear habitat have led to extensive conflicts with grizzly bears who seek out unprotected beehives for the honey and honey bee (*Apis mellifera*) larvae, and pupae. This chapter begins with a brief

background description of the RMF region and the study area. The bulk of the chapter emphasizes the history of livestock development in the region and how this industry adapted to the local environment and has dominated land use in the area. The concluding sections discuss the current spatial and temporal aspects of livestock management and beehive site locations in the study area, grizzly bear use of private lands, and how these conditions may affect human-grizzly bear conflicts.

BACKGROUND

The study area lies within a region of north-central Montana, USA that is popularly referred to as the “Rocky Mountain Front” (RMF) (Figure 4.1). This region is rich in natural and cultural history. Ancient marine limestones nearly 300 million years old contain an abundant fossil record that was uplifted to the earth’s surface over millions of years (Mudge, 1972). This continental upheaval resulted in a massive thrust belt that terminates abruptly creating a striking topographic front where mountains end and prairie begins (Figure 4.2).

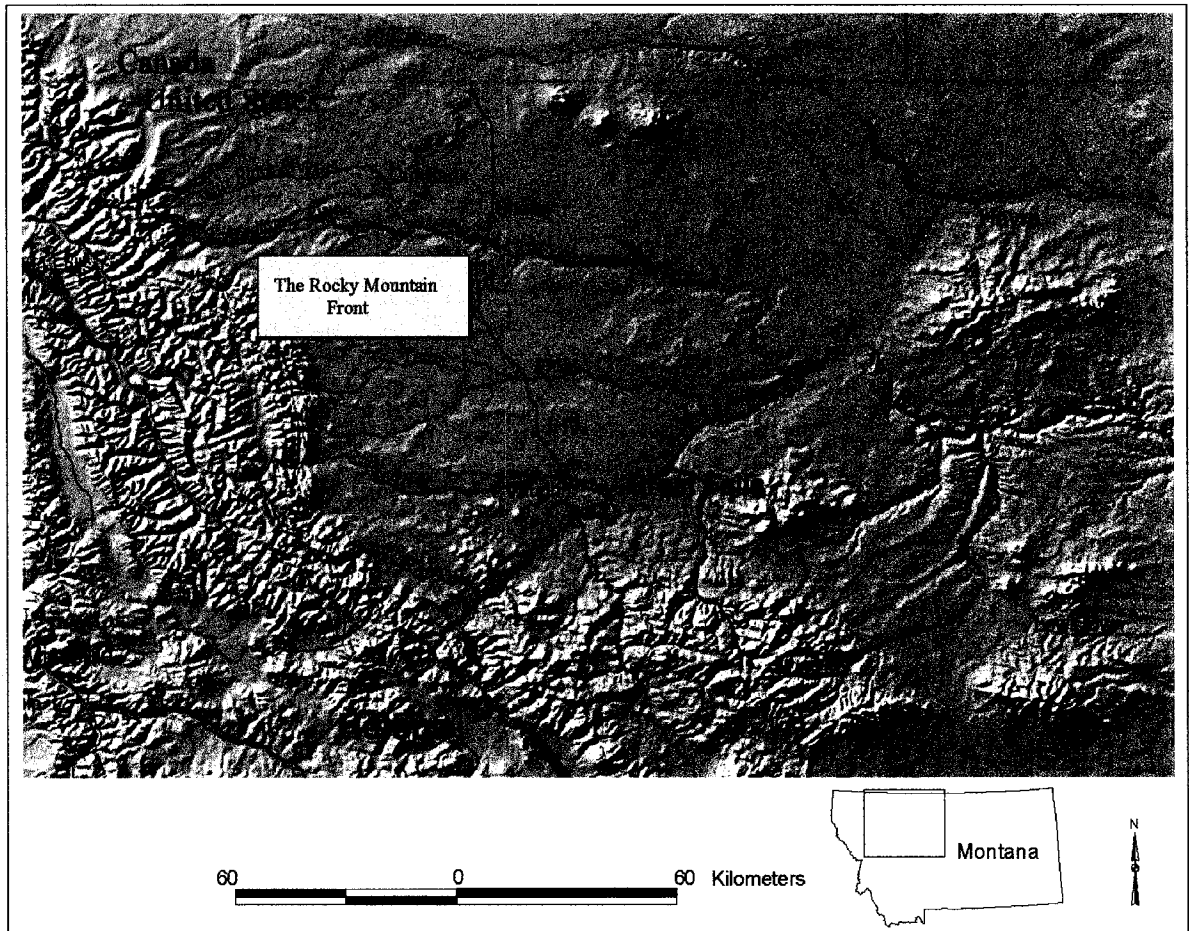
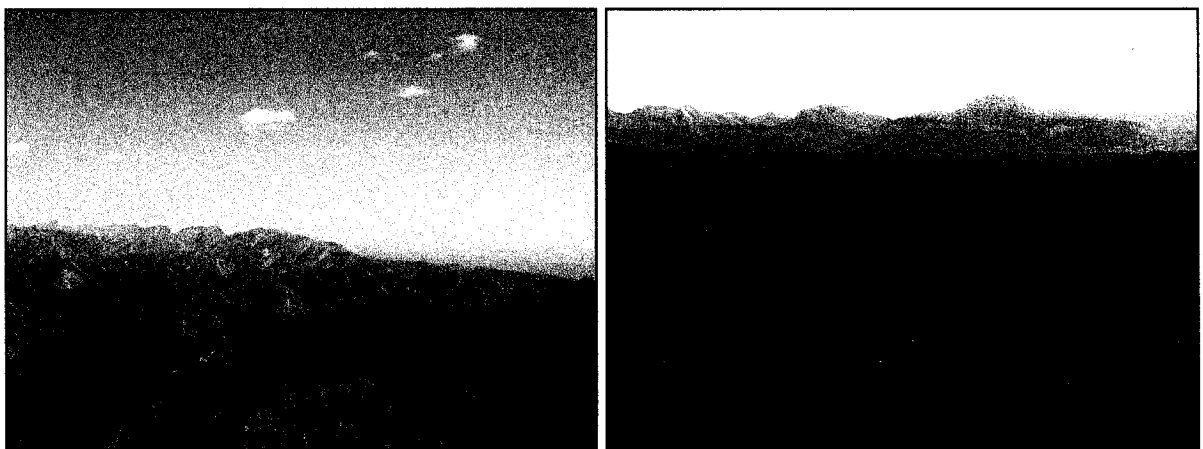


Figure 4.1. Overview map of the Rocky Mountain Front (RMF) in north-central Montana. While there is no definitive boundary for the RMF, it refers to the area south of the Canadian border to roughly the Dearborn River and west of I-15 to the mountains.



Photographs by author.
Figure 4.2. Sawtooth Range with thrust fault ridges (left) and foothill-prairie region on the Rocky Mountain Front (right).

Great herds of bison (*Bison bison*) blanketed the region prior to European settlement and were hunted for roughly 10,000 years by early Clovis hunters and more recently by modern Plains Indians until roughly the mid-to-late 1880s. Early Jesuit priests led by Adrian Hoecken came to present day Choteau in Teton County, in 1859 establishing a mission that would last only a year due to confrontations with the Blackfeet Nation. Settlers began trickling into the Sun River area in today's Teton and Lewis and Clark Counties during the 1860s and 1870s bringing oxen, cattle, and eventually sheep to a sparsely populated landscape as local Indian tribes were being forcibly relocated to reservations throughout the Montana from the 1850s to 1890s. By the 1880s the bison herds were largely decimated by hunting and early corporate free-range cattle operations filled the prairie grassland voids, particularly in east-central Montana. Eventually, cow/calf cattle ranching and dry land farming would dominate land use in this area (Malone and Roeder, 1976).

In many respects the human history of the Rocky Mountain Front is a microcosm of westward expansion and development in the United States. It still epitomizes America's fascination with the myths of rugged individualism and "manifest destiny." The nineteenth and early twentieth century artwork of Charles M. Russell and twentieth century writings of A.B. Guthrie Jr. romanticized and celebrated the region's landscape, wildlife, and history of settlement. As the habitat of the large mega fauna like bison, wolves, and grizzly bears was converted to human uses, these species were systematically eliminated throughout the northern Great Plains. However, the grizzly bear maintained a tenuous presence on its original prairie habitat, surviving in small numbers along a narrow ecotone of foothills-prairie.

LANDOWNERSHIP ON THE ROCKY MOUNTAIN FRONT

Unlike California, Oregon, Idaho, or Washington, the RMF has maintained populations of grizzly bears due to the area's proximity to large blocks of core habitat, early wildlife conservation efforts to protect habitat on public and private lands, and the remote location and low human population densities of the region. Large private ranches, thousands of hectares in size, characterize the region. The Nature Conservancy, an international land conservation organization, owns and manages the Pine Butte Preserve and oversees numerous conservation easements on private lands throughout the area. The privately owned habitat targeted by the Nature Conservancy has been invaluable for maintaining habitat for grizzly bears. The state of Montana owns and manages the Blackleaf, Ear Mountain and Sun River Wildlife Management Areas (WMA) and leases extensive parcels of state school trust lands to private ranchers and farmers for agricultural purposes. The Bureau of Land Management operates several Outstanding Natural Areas (ONA) along the Lewis and Clark National Forest border. Taken collectively, large amounts of public and private lands with limitations on human activities have, in part, provided habitat for grizzly bears along this mountain-foothills-prairie front region (Figure 4.3).

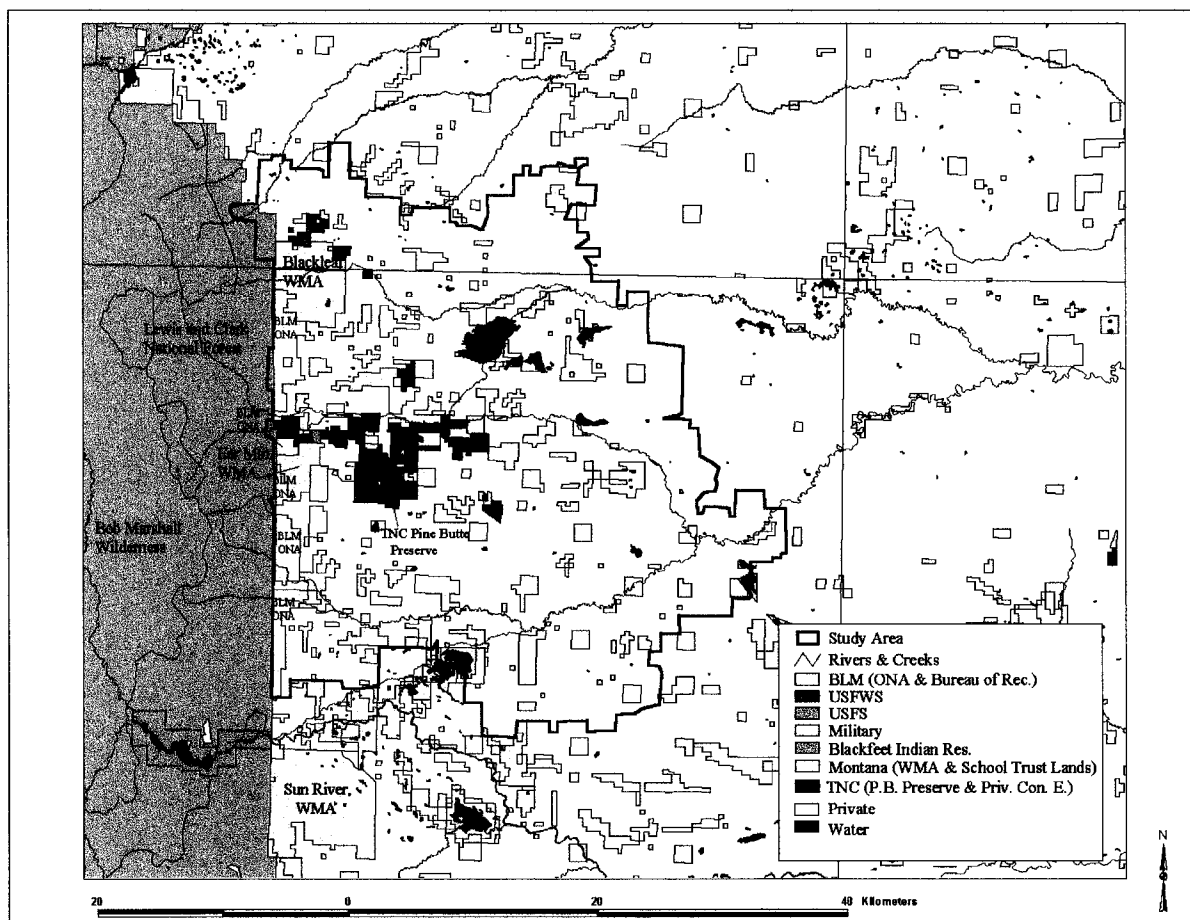


Figure 4.3. Generalized public and private ownership of the central Rocky Mountain Front area.

Yet the presence of grizzly bears has been controversial. Grizzly bears have been and still are reviled and revered by local residents. The grizzly bear symbolizes the appeal of American cultural self-definitions that champion both the subjugation and the conservation of wilderness (Wilson, 1996). In many respects it is remarkable that bears have maintained a sub-population along the RMF and the area is an excellent choice for studying human-grizzly bear conflicts on privately owned, low elevation foothill-prairie grasslands. The area is probably one of the only places that has continuously supported grizzly bears (populations levels have varied) on privately owned agricultural lands in the United States. Thus, it is an invaluable case study site to develop a better understanding

of the factors that predispose grizzly bears to conflicts with resident livestock producers. And perhaps most importantly, this case study site may offer a tangible example of how well private agriculturalists have adapted to the presence of the grizzly bear.

STUDY AREA

The study area is located in the central portion of the RMF. The study area was defined using fourth-order tributary boundaries of the upper Teton River watershed to the north and south. The study area was bounded on the west using the Lewis and Clark National Forest and on the east using the rough transition of rest-rotation cattle ranches to dry land farming. The study area is approximately 172,000 hectares (425,000 acres) and is drained by Muddy Creek, Deep Creek and the Teton River (Figure 4.4).

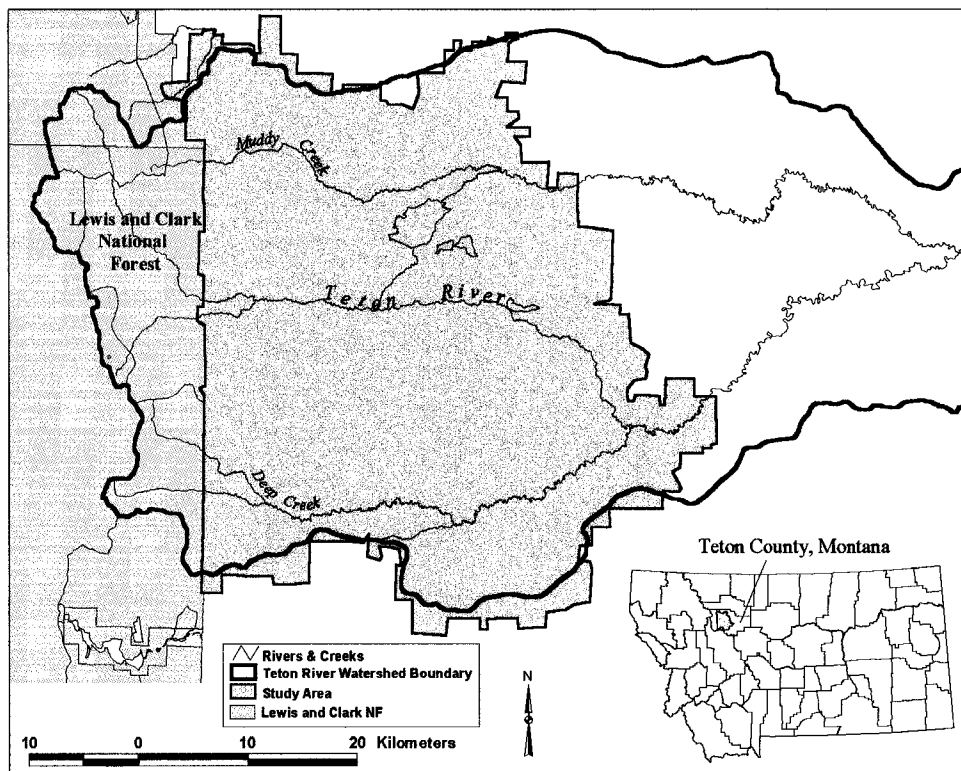


Figure 4.4. Study area location in North-central Montana.

The average size of a farm/ranche in the study area is 1,993 hectares (4,924 acres) and the median size is 981 hectares (2,424 acres). The most recent agricultural census data for Teton County lists 451, 989 hectares (1,116,889 acres) or 77 % of the land base in farms (USDA, NASS, 1997)

Census calculations for average farm/ranch size included land that was rented or leased. The National Agricultural Statistics Service defines “farms” broadly as any agricultural operation that produces more than \$1,000 in annual revenue. Since agricultural census data stops at the county level, Montana Department of Revenue (MDR) data for taxable parcels, Montana Department of Natural Resource Conservation (DNRC) grazing and agricultural lease data, and US Forest Service (USFS) and Bureau of Land Management (BLM) grazing permit data were used to calculate the acreage of land in the study area used for livestock production. All data were from 2001.

HISTORICAL DEVELOPMENT OF THE LIVESTOCK INDUSTRY

The development of the livestock industry on the RMF region has important ramifications for understanding the spatial and temporal patterns that, in part, underlie contemporary human-grizzly bear conflicts. Early settlement patterns by homesteaders and institutional mechanisms like roundup districts based on the natural topography of river basins facilitated the disposition of public lands to private ownership, particularly in the most productive river and creek bottoms. As the livestock industry went through boom and bust periods, eventually the midwestern style of livestock management took hold in this region and has resulted in cow/calf ranching operations that dominate land use along the foothill prairie zone. Spatial and temporal patterns of livestock management coupled with the seasonal foraging behavior of grizzly bears has led to

conflicts and grizzly bear mortalities on private lands. The following sections trace the historical development of the livestock industry in the region and then elaborate on how the overlaps of current land use practices and grizzly bear use of private lands have led to conflicts among humans and bears particularly along river and creek bottoms.

The Early Years: The Livestock Industry along the Rocky Mountain Front

The earliest cattle and agricultural attempts in Montana are generally attributed to Jesuit missionaries and early traders such as Pierre De Smet and John Owen in western Montana's Bitterroot Valley around the 1840-50s. Some of the first operators were those who saw market opportunities from commerce from the Oregon Trail. For example, Neil McArthur and Louis Maillet ranged their stock in the Bitterroot, Grass, and Jocko Valleys of present-day western Montana and sold their cattle to growing communities along the Columbia River (Fletcher, 1961). Malone and Roeder (1976) suggest that cattle operations in southwest Montana that served the mining industry as early as the 1860s formed a nucleus of "indigenous" stock growers that would eventually move into the north central part of Montana on the present-day Rocky Mountain Front area by the 1860s and early 1870s, to be joined by large-scale corporate operators by the 1880s. These early ranching efforts on the RMF were accomplished prior to these lands being technically and legally available for settlement. President Ulysses S. Grant's executive order of 1873 had granted lands north of the Sun River as the Blackfeet Nation, but ranches had been established by early stock growers like James Gibson along the Sun River by 1861 (Teton County History Committee, 1988; Keller, 1996).

By the 1870s and early 1880s an open or free-range style of pastoralism had become prevalent throughout the RMF region after a systematic cleansing of its native

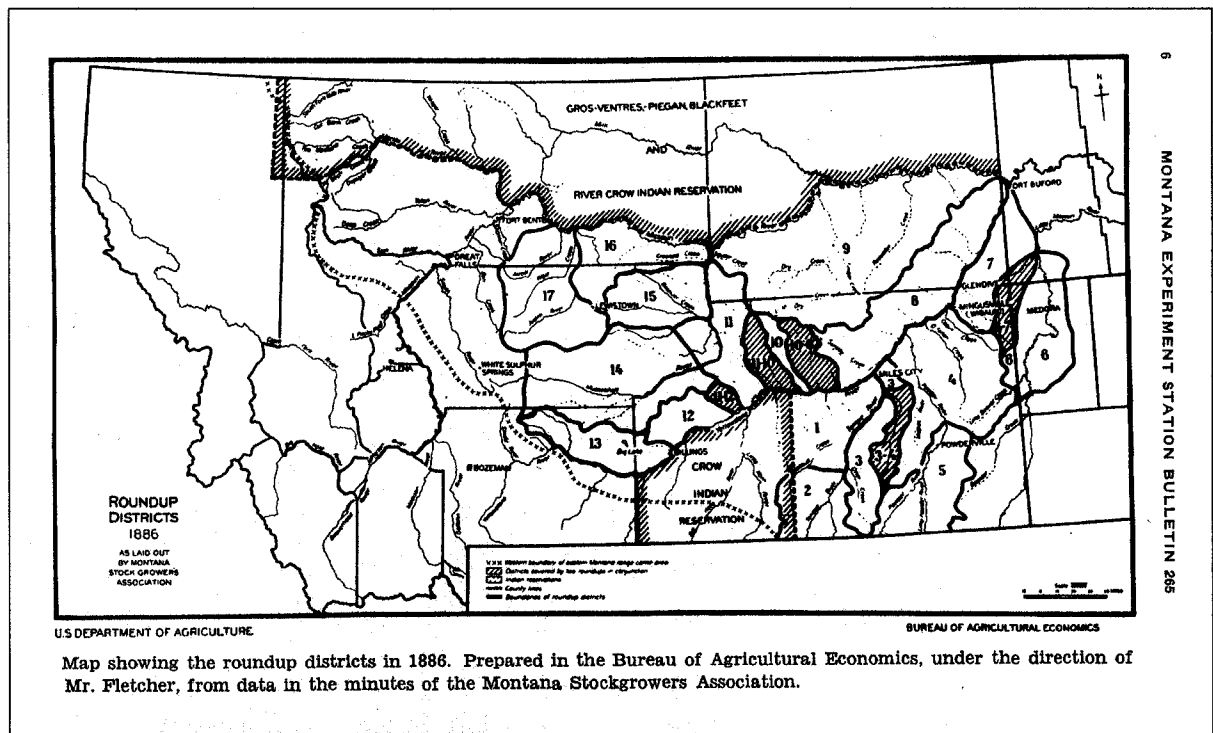
bison and extirpation and confinement of its Indian tribes to reservations. The result was a productive blue gramma (*Bouteloua gracilis*), needle-and-thread (*Stipa comata*), buffalo (*Buchloe dactyloides*), and western wheatgrass (*Agropyron smithii*) public grassland domain that caught the attention of local, regional, and foreign cattle interests. By the early and mid-1880s, large corporate investors from Texas, England, France, and Scotland were raising long-horns from Texas and short-horned breeds from the Mid-west and Oregon like Herefords and Black Angus throughout the RMF region and central and east portions of the Montana Territory (Bennett and Kohl, 1995; Malone and Roeder, 1976). These large corporate operations tended to be speculative, investor driven, and often overstocked the public domain (Worster, 1992). These outside interests minimized capital investments and rarely used fences, barns, or corrals. Labor was abundant and cheap and cowhands were most likely Hispanic or Black (Worster, 1992).

Fletcher (1960) estimated that in the central Montana Territory alone, there were roughly 600,000 cattle and sheep at the height of the open range boom and one estimate for the Muddy and Blackleaf creek area (see Figure 4.4) on the RMF reported nearly 15,000 sheep (Sun River Valley Historical Society, 1989). It is difficult to accurately estimate the total numbers of livestock that were being raised in the RMF area during the open range boom of the 1880s, but a conservative figure would probably be at least 25,000 to 50,000. Keller (1996) provides a more complete discussion of livestock density estimates for the area and a detailed environmental history of the RMF.

During this open range period, watershed boundaries were used to organize roundup districts under the auspices of the Montana Stock Growers Association that formed in 1886. The natural topography of drainage basins like the Teton and Sun Rivers

helped contain ranging livestock and the roundup districts served to organize and to help allocate different herds to their owners through unique brands (Fletcher, 1932) (Figure 4.5). Malone and Roeder (1976:120) suggest that early ranchers in these areas laid claim to “accustomed range which neighbors ordinarily recognized as private property, even though the land was public domain.” Roundup districts served as some of the first informal or customary property markers on public lands. Moreover, those livestock producers who actively used the roundup districts for their cattle and later formed grazing associations were in an advantageous position to take hold of the most productive river and creek bottomlands once homesteading laws transformed the public domain to private ownership.

Cooperation among stock growers within roundup districts and eventually grazing associations was partially a matter of business survival— after the spring and fall roundups, cattle were sorted to their respective owners who were members of the grazing associations. However, these associations would serve other livestock interests as well. A chief purpose was to defend free ranging stock from Indians who left reservations to steal cattle and sheep to augment their poor living conditions and to offer privately funded bounties on wolves, coyotes, and other predators (Dale, 1960; Fletcher, 1932).



Source: Montana State College Agricultural Experiment Station. Bulletin. No. 265:1-63. 1932.

Figure 4.5. Roundup districts in 1886 for central and eastern Montana complied with the USDA Bureau of Agricultural Economics under the direction of R.H. Fletcher (1932). Note that the Teton and Sun Rivers and Deep, Dupuyer, and Birch Creeks are found in the north-central portion of the map below the Gros-Ventre-Piegan and River Crow Indian Reservations. Deep Creek and the Teton River are found in the study area.

Settlement Patterns

Natural topographical boundaries like watershed divides and the desire to be in close proximity to rivers and creeks influenced settlers' geographical choices for establishing ranches (Helburn, 1956). Jordan (1993:302) wrote that, "The annual spring thaw caused meltwater-fed streams to spread out over the flats, providing good opportunities for haying. Abundant natural meadow was perhaps the single most important criterion in selecting ranchstead sites." It is likely that those stock growers who established operations early and were part of round up districts were in a favorable

position to obtain private ownership of those same lands during the subsequent homestead boom. An observer from 1880 who traveled through the RMF area wrote:

The Upper Sun River Valley is settling up rapidly, and with a good class of people...many of the new settlers have families...and the agricultural interests of the Sun River country are independent and promising. The farmers here have good farms and ample irrigation facilities and ready markets, and with such advantages the community will certainly grow more prosperous from year to year. (Harding, 1880:3).

These observations suggest that farmers had already made investments in irrigation facilities and were taking a long term approach to land management assuming that the public domain they were improving with their labor would eventually become privately held. Moreover, many of these early livestock producers established their base of operations in close proximity to rivers and creeks for domestic water use, fuel wood, building materials, shelter, stock watering, and eventually for forage production as ranches became more spatially fixed and dependent on hay and other forage for winter feeding.

The open range boom of the 1880s would dramatically decline after the severe winter of 1886-1887, which affected ranchers from southern Colorado to Canada (Briggs, 1940). The open range approach to cattle rearing had largely been a laissez faire management style. Cattle were typically left on their own to find forage and to contend with the elements and predators. An overstocked prairie grassland along with drought conditions in 1886 followed by severely cold temperatures, deep snows, and multiple blizzards in 1887 would prove disastrous to cattle that could not find enough forage to survive. While estimates vary, losses of 40 to 60 percent were common. In Montana, 663,716 head of cattle were assessed for taxation in 1886 and in 1887 the number had fallen to 471,171 (Dale, 1960). Coupled with low cattle prices during 1887 and

significant livestock losses, many individual ranchers and outside corporate interests filed for bankruptcy or quit the business (Dale, 1960). In Montana, those ranches that survived through the winter of 1886-1887 would improve and or adapt their methods to meet environmental conditions.

Adaptations to the Environment: The Midwestern Style of Ranching

Some of the most significant changes in ranching methods included: a reduction in herd size, a focus on breeding livestock docility, an increase in the use of fencing for wild and irrigated hay meadows and for containing livestock, winter feeding of stock, and diversified operations including dairy cows and sheep (Linfield, 1903, Dale, 1960).

Jordan (1993) suggests that the midwestern style of cattle ranching became firmly established in the Rocky Mountain West during this time contrary to the popular myth that the Texas style gave birth to the modern cattle industry in places like Montana. He described the main characteristics of the midwestern style in the following passage:

Fundamentally different from its hispanicized western competitors, the midwestern herding system, reflecting dominantly British influences, was distinguished mainly by greater attention to the welfare and quality of the livestock. Pursuing methods that were both more capital and labor intensive, the Midwesterners exercised greater diligence in the care of cattle than either the Texans or Californians, achieving in the process herd docility. They provided winter feed for the animals; strove to upgrade the bloodlines of their herds through selective breeding, even importing British stock; shifted livestock seasonally between pastures, often so profoundly as to involve transhumance; formed stock raisers associations; possessed rather minimal equestrian skills; made extensive use of stock pens, and erected at their early convenience, pasture fences; derived some milk and butter from their herds; and produced lean cattle for overland driving to areally segregated Corn Belt fattening districts, replicating the ancient British pattern of Celtic breeders and Saxon feeders. (Jordan, 1993: 267)

This change in pastoralism to the Midwestern style coupled with the Desert Land Act of 1877, the Enlarged Homestead Act of 1890 and subsequent homestead boom and rise of dry land agriculture in the early 1900s facilitated the disposition of the public

domain to private ownership. This shift in land ownership and land use from the public, open range, resulted in an increase in smaller cattle and farming operations that were owned and operated by individual families versus large corporate businesses (Bennett and Kohl, 1995). Corporately owned ranches did not disappear, but were not as prevalent after the severe winter of 1886-1887. In a review of Montana State College Agricultural Experiment Station Bulletins from 1900 to 1935, the bulk of experimental studies and reports focused on dry land farming techniques, economic feasibility studies of crop types, winter forage studies for cattle, and other horticultural studies that would presumably assist newly arrived homesteaders whose operations tended to be smaller and diversified. As livestock producers adopted winter-feeding as a necessary component of a successful operation, fencing and irrigation for forage production increased throughout Montana. Norton (1931) reported that irrigated alfalfa was the most widely grown forage crop in Montana in 1929 with nearly 304,000 hectares (750,000 acres) in cultivation compared to approximately 23,000 hectares (56,000 acres) in forage production in 1880 (Malone and Roeder, 1976). By 1997, there were 1,012,000 hectares (2,500,000 acres) of land in forage production in Montana (USDA, NASS, 1997).

Land Use for the Rocky Mountain Front Area: 1900s-1940s

Throughout the early twentieth century in central and eastern Montana, homesteaders moved to the RMF region attempting dry land farming and or livestock rearing in what would be the last great land rush in US history (Malone and Roeder, 1976). By the mid and late-1920s, drought conditions coupled with a crash in commodity prices followed by the Great Depression of the 1930s would result in a depopulation of the northern and central great plains and eventually a steady increase in farm and ranch

size due primarily to consolidation and mechanization during and following World War II (Opie, 1987; Baltensperger, 1987). In 1930, the average farm/ranch in Montana was 380 hectares (940 acres) in size, increased to 1,021 hectares (2,522 acres) by 1969 and stabilized at 1,038 hectares (2,566 acres) by 1982 (USDA, NASS, 1997; Baltensperger, 1987). In 1997, the average size of Montana farms/ranches had slightly decreased to 977 hectares (2,414 acres) and the average size of farms/ranches in Teton County was 811 hectares (2,005 acres) (USDA, NASS, 1997). One section of land in the US Federal Survey is 640 acres (Platt, 1996).

Teton County farms and ranches did not experience the same rates of consolidation that other counties in the Great Plains did from post-WWII to the mid-80s. The average increase in farm/ranch size in Teton County was between zero and five percent from 1930-1935, increased to between 10 and 20 percent from 1940-1945, was between zero and five percent for 1950-1954 and 1965-1969, and would decrease over 5 percent by 1978 (Baltensperger, 1987). Baltensperger (1987) found that counties that had more ample rainfall may not have felt the effects of periodic drought as acutely as did regions like the central Great Plains. This suggests that consolidation to larger ranch and farm operations in highly drought prone areas was a risk minimization strategy to adapt to environmental conditions by accumulating additional agricultural lands for more management options. Wetter microclimatic conditions along the Rocky Mountain Front may be one explanation for a slower rate of ranch/farm consolidations compared to other counties in the state. Other factors such as the additional costs of land acquisition may have played a role as well.

On the RMF, sheep operations would increase throughout the late 1890s and peak by the 1930s and eventually decline to small levels throughout the rest of the century (Keller, 1996; USDA, NASS, 1997). For Choteau County, the US Department of Commerce (1890) estimated that there were nearly 460,000 sheep by 1900. Cattle operations on the RMF historically were more diverse than the present by the measure of age classes and sex of animals produced. For example, Saunderson and Richards (1931) reported that for the RMF and foothills region that cows (43 percent), calves (29 percent), yearlings (17 percent), and 2-3 year-old steers (11 percent) made up the marketable cattle population. Cow/calf ranching operations increased from Post WWII to the present. Currently, along the RMF and in the study area, stock growers are producing almost exclusively calves for market and cattle are the dominant type of livestock produced in the region.

SPATIAL AND TEMPORAL ASPECTS OF CURRENT LAND USE PRACTICES

Currently, rest-rotation, cow/calf operations dominate land use along the RMF and are characteristic of the Midwestern style of ranching operations. This British inspired style of pastoralism has proven successful in the Rocky Mountain West largely due to adaptations to a seasonally cold environment through winter-feeding, emphasis on breeding lines, and promoting herd docility. Many of the early ranches along the RMF that were the precursors to today's cow/calf operations were settled near naturally occurring rivers and creeks to capitalize on native wild hay meadows and subsequently made irrigation improvements to increase forage productivity. The Midwestern-Anglo style of ranching coupled with private ownership has allowed ranchers to invest significant capital for investment in farm machinery, irrigation improvements, stock

watering devices, corrals, barns, and calving barns that result in discrete patterns of land uses that tend to be spatially fixed in the landscape.

Livestock Management

Ranch residences, barns, corrals, and calving areas generally are located near rivers and creeks and extensive fencing and irrigation developments are integral components of operations. Pastures are typically rested and cattle are rotated from calving areas to spring, summer, and fall pastures using various combinations of private land, leases, or informal “pasture agreements” among neighbors throughout the study area. Grazing and agricultural leases on state school trust parcels are vital to many operations throughout the study area as permits for grazing on neighboring USFS and BLM lands have decreased in the past several decades (USDA, 1986,1993,1999).

Spatial and Temporal Aspects of Calving

The majority of livestock producers in this area “open-calve” or use a combination of corrals, barns, and adjacent pastures for the 60 to 70 day calving season that typically begins in February and ends in late April or early May. This calving style and timing overlaps with the emergence of grizzly bears from their dens and likely influences the ability of grizzly bears to find and predate upon livestock. Grizzly bears typically leave their dens between April 12 and May 9 along the RMF, and all but females with newborn cubs leave their dens in early April (Aune and Kasworm 1989). Phenological changes in riparian vegetation attract grizzly bears to low elevation river and creek bottoms during roughly the same time that ranchers are calving. Spring cow-calf pastures and sheep lambing areas also tend to be located near rivers and creeks in the study area (Figure 4.6). Calves are especially vulnerable to predation during “turn-out”

or movement of cow-calf pairs from the calving areas to spring pastures. Calves are small and have had limited experience with predators. Additionally, calving areas can contain afterbirth and it is not uncommon for grizzly bears to find and consume this source of protein (M.J. Madel, per. comm. January 10, 2003). Grizzlies that may be attracted to calving areas are also likely to be in close proximity to ranch residences and as a result, may find other human based foods that can lead to conflicts.

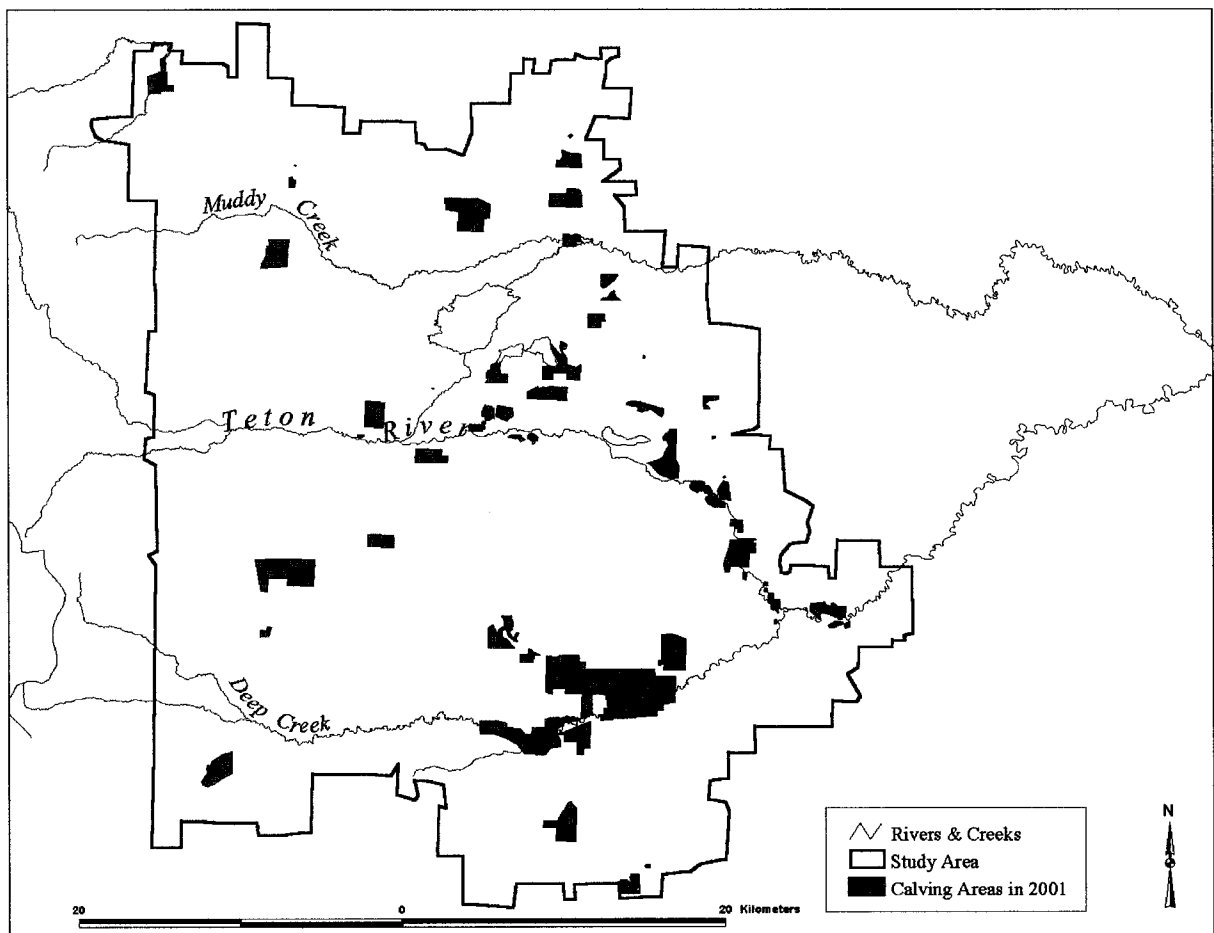


Figure 4.6. Distribution of cattle calving areas in study area for 2001.

Spatial and Temporal Aspects of Bone Yards

Bone yards or carcass dumps are discrete sites where ranchers have typically left dead livestock to decompose on their private lands. Techniques vary, but many ranchers simply pile dead animals in a specific location, others dig “carcass pits”, and others sometimes attempt to bury carrion. Many bone yards are located near calving areas and lambing areas presumably as a labor saving technique. During the calving season, operators are constantly monitoring the birthing process and it may be a matter of convenience to dispose of dead calves or cows in locations near the calving areas (Figure 4.7). Bone yards have been problematic for grizzly bears and livestock producers since these attractants draw bears in for scavenging opportunities and can lead to food conditioning and grizzly bears that are habituated to human activities (Madel, 1996). Bone yards tend to accumulate dead livestock particularly during and after the calving season and overlap with den emergence of grizzly bears making livestock carrion readily available to bears that forage in lower river and creek bottoms in the early spring.

Montana Department of Fish, Wildlife and Parks have a carcass redistribution program where carrion from participating ranches that are placed on bone yards are collected in the spring and randomly redistributed to remote locations along the RMF. Livestock producers started participating in the program at various times during 1986-2001 and this change in management practices has helped reduce conflicts along the RMF (Madel, 1996).

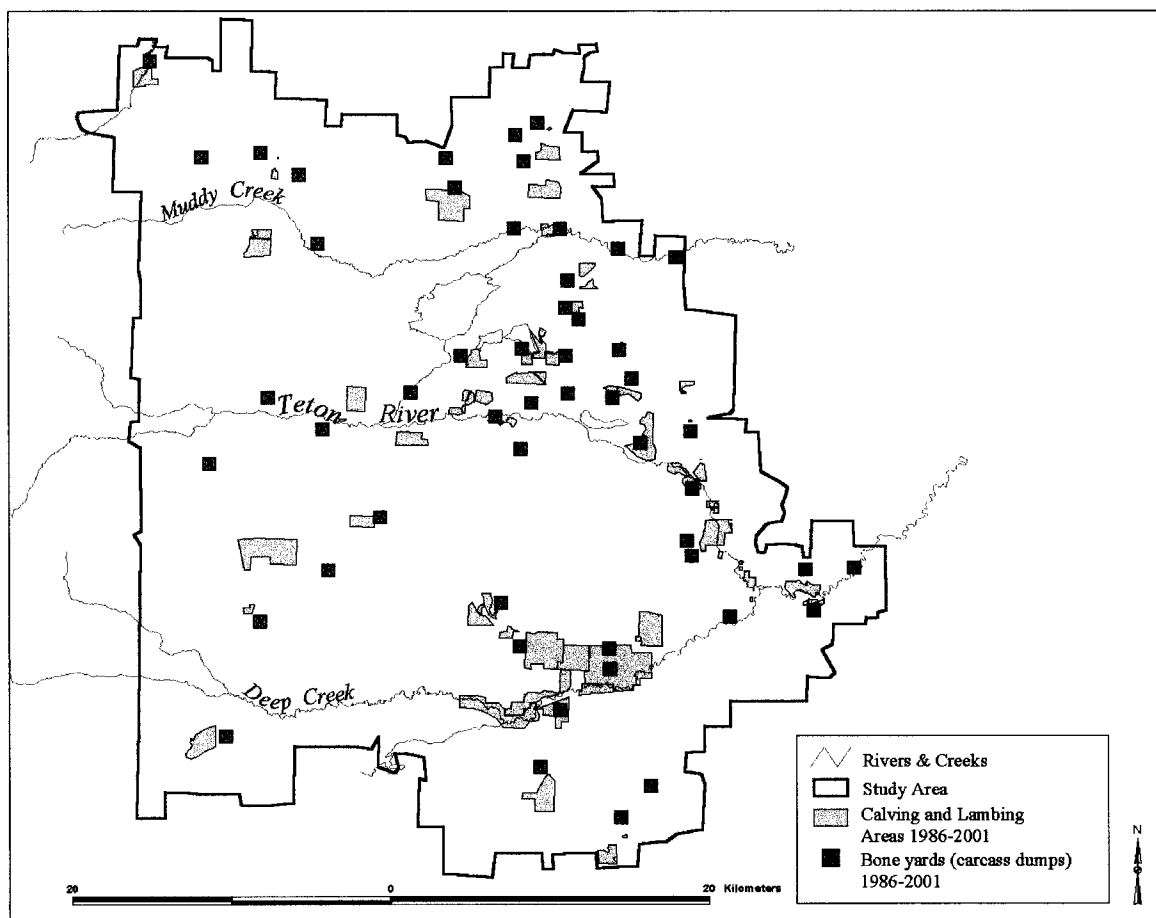


Figure 4.7. Calving and lambing areas and managed and unmanaged bone yards for 1986-2001.

Beehive Site Locations

Early honey bee use in Montana started roughly in the late 1850s and early 1860s. Records suggest that beekeepers were producing honey in the West as early as the 1840s in Utah and in present day Oregon, Washington, and British Columbia by the 1850s (Williams, 1975; Crane, 1999). The earliest known registered beekeeper in the state of Montana, established a “territory” in 1900 in Carter County. However, from the 1900s through WWII, territories among beekeepers were regulated by informal “gentlemen’s agreements.” The rationing of sugar during WWII and an increased reliance by the nation on honey as a sweetener, lead to formal regulations and laws pertaining to apiary

licensing in Montana by the 1940s. As part of the home front effort, Montana beekeepers were given exemptions from the wartime draft to manage and increase honey production at home (L. Hinck, per. comm. February 21, 2003). Additionally, American foul-brood disease from a bacterium (*Bacillus larvae*) that spreads from hive to hive infecting larvae and killing bee pupae, led the state of Montana to establish a 3 mile buffer among neighboring beekeeper territories that is in effect today. Territories also served to minimize overcrowding of beekeepers during low flow nectar years (MT Department of Agriculture, 2003). Montana is one of the few states in the country that has a spatially regulated apiary licensing system for the 86 commercial registered beekeepers in the state. “Commercial beekeepers” refers to operators who place, by permission or through rental agreements, more than 5 hives on a site, typically on private lands (MT Department of Agriculture, 2003).

Commercial beekeepers along the Rocky Mountain Front have been operating since the early 1940s. Within operating areas, commercial beekeepers are required to license and report the locations of each site, referenced to the quarter section. All licensed sites are required by law to be used for a minimum of 10 days during the nectar flow or the license for that site is revoked by the state. The state of Montana collects annual colony registration fees and has 5 districts and 8 bee inspectors who monitor beehive operators (MT Department of Agriculture, 2003). These licensing requirements by the State of Montana have resulted in clearly defined territories among commercial beekeepers who have an incentive to use or lose all of their licensed sites within their area. Hence, territories are considered a lucrative right and many are passed on through generations of family beekeepers (Cunniff, per. comm. February 14-15, 2003). Along the

Rocky Mountain Front, there are 5 commercial operators, one of whom managed all beehives in the study area.

The legal requirements that regulate commercial beekeepers coupled with local ecological conditions have resulted in spatially dispersed beehives sites over large areas depending on colony size. Moreover, the ability to produce high quality and abundant honey depends on four factors: nectar sources, pollen, water, and access (J.J. Bromenshenk, per. comm. February 13, 2003). In the study area, licensed beehives sites tend to be near rivers, creeks, and irrigation facilities. Irrigated alfalfa typically grown in and near river and creek bottoms is considered by beekeepers to produce clear light grades of premium honey. Honey bees are considered “nectar robbers” with respect to alfalfa since they can learn to extract large quantities of nectar from alfalfa plants without tripping a release of pollen from the anther of the flower that normally showers pollen onto a honey bee inhibiting a bee’s ability to carry nectar (Bromenshenk, per. comm. February 13, 2003; Gould and Gould, 1988). Thus, excess nectar beyond what is needed for food and to raise a brood of workers bees, results in a honey surplus that beekeepers harvest. In the study area it is common that river and creek bottoms are used for alfalfa production with two, sometimes three cuttings possible, depending on annual moisture conditions. This cropping pattern results in pulses of surplus honey due to the efficient extraction of nectar during the flowering cycle of alfalfa by honey bees. Beehive sites located along rivers and creeks may also capitalize on nectar sources from native forbs and tree sap (propolis) found in riparian areas that augment supplies of honey (Gould and Gould, 1988). Pollen is also needed by honeybees along with water, nectar, and a variety of enzymes (invertase and oxidase) to produce protein for honey bees (Seeley, 1985).

Pollen is abundant in plants like big sagebrush (*Artemisia tridentata*), a species common to the prairie grasslands in the study area. Water is also necessary for honey bees to cool themselves and hive temperatures through evaporative cooling and for consumption (Seeley, 1985). Hence, beehive sites located near irrigated alfalfa, riparian areas, and prairie grasslands may be in optimal locations for producing honey (Bromenshenk, per. comm. February 13, 2003). Road access also is an important criterion for locating hives in productive sites.

The local honey producer has explained that all four factors are important in his decisions for locating and licensing beehives, but that he considers nectar first when making decisions for hive locations (Cunniff, per. comm. February 14-15, 2003). Additionally, he considers the number one source of nectar in his operating area to be irrigated alfalfa (Cunniff, per. comm. February 14-15, 2003). Thus, it is evident that beehive sites in the study area are clustered along river and creek bottoms in several locations (Figure 4.8). The average distance of beehives (n=40) located in the study area boundary to the nearest river or creek edge is 2.4 km. Beehives are typically used from approximately late May to early June to October 15th in the study area (Cunniff, per. comm. February 14-15, 2003).

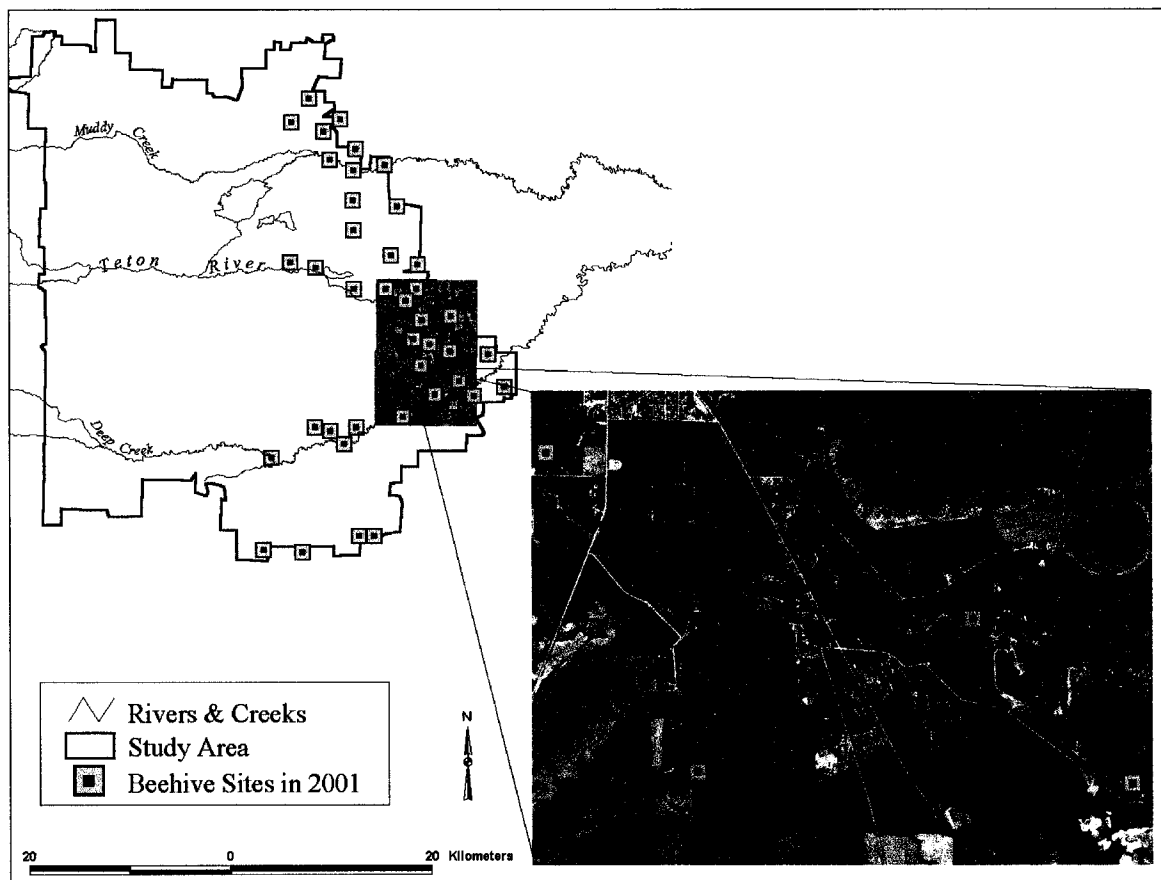


Figure 4.8. Distribution of beehives sites in 2001 with inset that reveals an example of beehives sites located in proximity to irrigated alfalfa, rivers and creeks, and road networks for a portion of the study area.

GRIZZLY BEAR USE OF PRIVATE LANDS

According to the US Fish and Wildlife Service (1993) there are only five areas in the coterminous 48 states that support either self-perpetuating or remnant populations of grizzly bears. Most of this remaining habitat is on publicly owned national parks, national forests, and wilderness areas in Idaho, Montana, and Wyoming (Hoak et al. 1981, Servheen 1990, Servheen et al., 1999). The Northern Continental Divide Ecosystem (NCDE) includes Glacier National Park, parts of the Flathead and Blackfeet Indian Reservations, sections of five national forests (Flathead, Helena, Kootenai, Lewis & Clark, and Lolo), Bureau of Land Management parcels, and a significant amount of

state and private land (USFWS, 1993). The NCDE is unique in that it contains a narrow strip of foothill and prairie habitat along the eastern slope of the Rocky Mountain Front (RMF) that is a mixture of public, state, tribal, and private lands. Despite the multiple jurisdictions and land management objectives, the RMF is the only place in the lower 48 states where bears still use their historic prairie grassland habitat (US Fish and Wildlife Service, 1993).

Aune and Kasworm (1989) found that on the Birch-Teton Creek Bear Management Unit (BMU) (Figure 4.9), approximately 80 % of grizzly bear spring habitat was found on private lands with less than 5 percent slopes and were primarily fens and riparian communities. The riparian areas used by bears provided important foraging opportunities, cover, and secure habitats for movement (Aune and Kasworm, 1989). The researchers also found that “low-land bears” moved from their denning habitat on the national forest to low elevation habitats in riparian areas until the pre-denning and denning periods. “Backcountry bears” used the privately owned riparian habitat during the spring and returned to higher elevations during the summer and fall. Grizzly bears in the Teton River area showed a higher fidelity to riparian lowlands than did bears in the watersheds to the north (Badger-Two Medicine area) and south (Sun River areas). This is consistent with observations by M.J. Madel (per. comm. January 10, 2003) who has found that females with cubs often have overlapping home ranges on low elevation private lands and spend extensive periods of each year on private agricultural land.

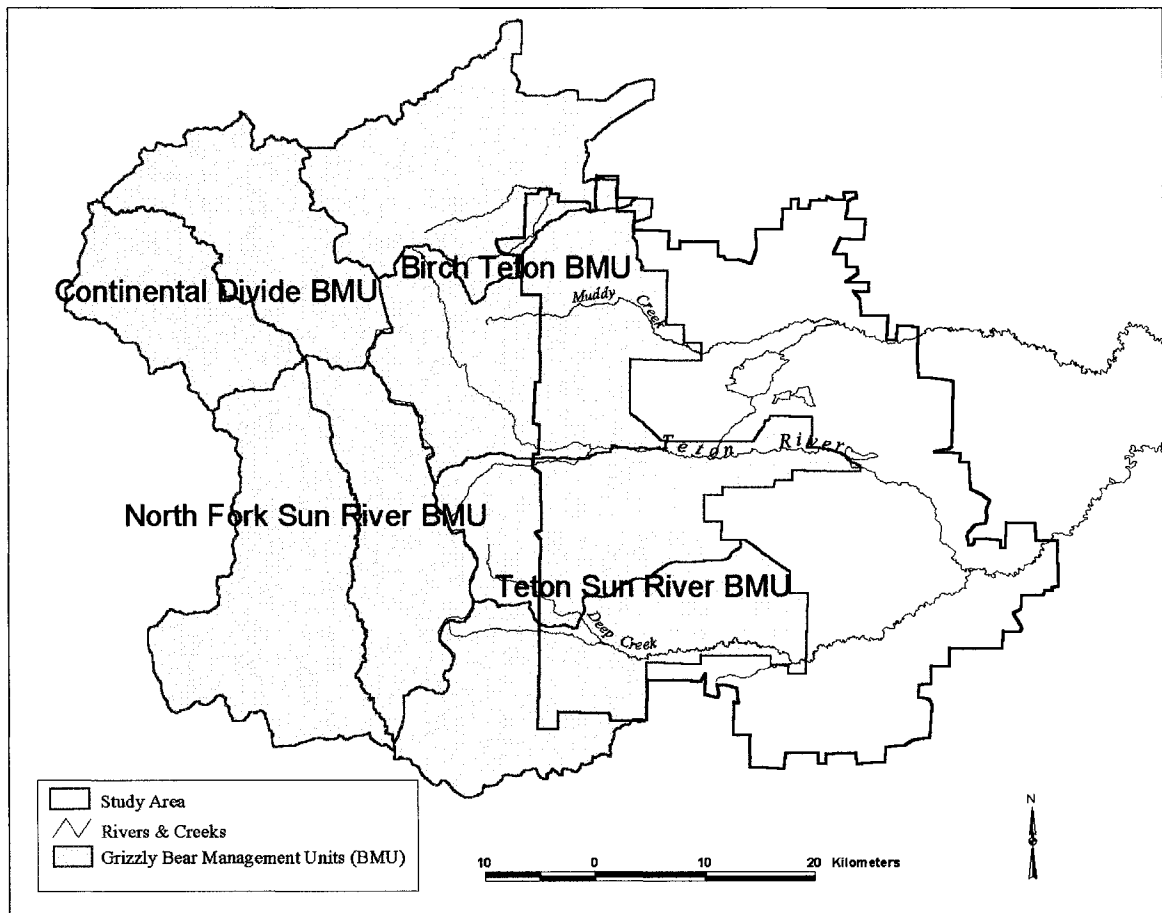


Figure 4.9. Bear management units (BMU) near the study area.

Montana Fish, Wildlife and Parks has observed a slow and steady increase in the number of females with cubs over the past 16 years and suggest that a highly conservative estimate of the number of unique individual grizzlies that may use the study area boundaries in a given year is approximately 50 (M.J. Madel, per. comm. January 10, 2003). Additionally, Madel (per. comm. January 10, 2003) has observed that seasonal densities of grizzly bears have been highest along the Teton River and watersheds to the north.

CONCLUSIONS

The extensive use of private lands by grizzly bears in the study area has resulted in human-grizzly bear conflicts (Madel, 1996). The spatial locations of livestock operations and seasonality of animal husbandry practices like calving and bone yard use overlap with grizzly bear habitat resulting in available attractants to grizzly bears. Additionally, the midwestern style of ranching has favored selective breeding that produces herd docility and invariably, breeds of cattle that are inherently vulnerable to predators. With the center of ranch operations typically located near water sources and hence grizzly bear habitat, livestock-grizzly bear conflicts have been extensive in the RMF area over the past 20 years. Additionally, beehives that are an attractant to grizzly bears tend to be in close proximity to grizzly bear habitat. These historic and current land use patterns have resulted in a concentration of livestock, specifically cows and calves, and beehives on privately owned and leased land. These same areas are low elevation spring and fall grizzly bear habitats and attractants like calves, calving areas, bone yards (carcass dumps), or spring cow/calf pastures and beehives are available to foraging grizzly bears.

CHAPTER 5: INTERACTIVE MAPPING: IDENTIFYING LAND USES AND ATTRACTANTS THAT IMPACT GRIZZLY BEARS

ABSTRACT

Grizzly bear (*Ursus arctos*) conflicts and mortality risks associated with human activities on private agricultural lands are of concern to bear management and recovery efforts in North America. In portions of Montana, livestock abundance and other attractants near core bear habitats lead to food conditioning and subsequent removals of grizzlies from local populations. The spatial complexities of livestock management practices and attractant availability on private lands and the impacts these have on grizzlies are not well understood. As part of a multi-year research effort to understand the factors that predispose grizzlies bear to conflict and mortality risks on privately owned agricultural lands, we developed a data collection technique we call interactive mapping using a Geographic Information System (GIS). We discuss the technical and practical aspects of working one-on-one with livestock related land users (LRLU) using laptop computers to digitize land use practices and attractants that may affect grizzly bears. We conducted a census of livestock related land users in a defined study area in north-central Montana that resulted in 61 interactive mapping sessions out of a possible 64. We had participants digitize calving areas, spring, summer, and fall pastures and carcass dumps or bone yards. Additionally, we had participants spatially locate suspected grizzly bear conflicts on their private or leased lands. We also worked with the local honey producer and digitized beehive sites in the study area and documented what beehives had been protected with electric fencing. We had a 95% response rate and have found that interactive mapping, as a data collection technique is an accurate and efficient means of eliciting and displaying meaningful spatial information from livestock related

land users. We discuss the applications of our techniques for integration with grizzly bear management and as a method for working with rural landowners and wildlife managers.

INTRODUCTION

The long-term prospects for conserving grizzly bears (*Ursus arctos*) in the lower 48 United States are challenging. Despite decades of effort and scientific research, recovery of grizzly bear populations is not assured. Debate continues over the robustness of grizzly bear populations and management approaches (Boyce et al. 2001b; Mattson and Craighead, 1994; Clark et al., 2001). The majority of grizzly bear mortality in the lower 48 United States is spatially concentrated on the periphery of occupied grizzly habitat (US Fish and Wildlife Service, 2003). In the western United States, portions of grizzly bear spring and fall habitats occur on privately owned and managed agricultural lands. Food conditioning of grizzly bears by humans is a mechanism that causes conflicts and is a leading reason for management removals of grizzlies from populations in Montana (Mace and Waller, 1998). The overlap of humans and grizzly bears on private lands has led to heated debates among landowners, conservationists, and management agencies over population sizes, growth trends, and risk of human injury (Primm, 1996). Few studies have examined human-grizzly bear conflicts on private agricultural lands despite the relevance to grizzly bear recovery (Servheen, 1989). We describe a research method using ArcView[®] GIS v3.2 for mapping land use practices that affect grizzly bears and as a useful technique for collecting and displaying data and sharing information among researchers, managers, and private landowners.

We integrated laptop computers and interactive GIS mapping interviews with livestock related land users who participated in a data collection effort for research on human-grizzly bear interaction on private agricultural lands. Our rationale for engaging livestock related land users in interactive mapping is to learn more about innovative land use and animal husbandry practices that minimize predator opportunity and to integrate these findings with existing data sets generated by wildlife professionals. Additionally we sought to develop a method that helps improve communication among often-divergent interests regarding grizzly bear recovery. Maps can be a powerful heuristic tool for mutual learning to occur among participants, scientists, and managers.

We document the data needed for this research technique and illustrate the methods and protocols used. Our methods and data will have broad applications for spatial statistical modeling of factors that affect the likelihood of human-grizzly bear conflict. However, in this paper we emphasize the technical steps involved for working one-on-one with livestock related land users to digitize their management practices and attractant sites that affect grizzly bears. While the use of laptops is not new to wildlife management and other professions, our technique offers insight to researchers and professionals who are involved in wildlife and land conservation (Anthony and Stehn, 1994; Daniels and Halik, 1997).

STUDY AREA

The study area is located in north-central Montana and is delineated by the upper Teton River Watershed. Because our research focuses on private lands, we bounded the study area on the west using the Lewis and Clark National Forest boundary and on the east using the rough transition of rest-rotation cattle ranches to intensive winter wheat

farms. The north and south boundaries of the study area were based on the Teton River watershed. The study area is approximately 172,000 hectares (1,720 km²) (Fig. 5.1). Approximately 80% of grizzly bear spring habitat in this area is found on private lands primarily in fen and riparian habitats. Along the RMF, a steady increase in observed numbers of females with cubs has been observed over the past 16 years. Based on this estimate and our study area size, approximately 50 grizzlies may use the study area during a given year (M.J. Madel, personal communication, January 10, 2003.). The riparian areas used by bears provide critical seasonal foraging opportunities, cover, and secure habitats for movement (Aune and Kasworm, 1989). Ranch operations tend to be located along creeks and river bottoms in this area and unsecured attractants like calving afterbirth, calves, lambs, beehives, or garbage are easily found by grizzly bears. The concentration of bear use in these areas has resulted in large numbers of human-bear conflicts in the form of cattle depredation and property damage. From 1991 to 1994, 82% of all human-bear conflicts were attractant related (Madel, 1996).

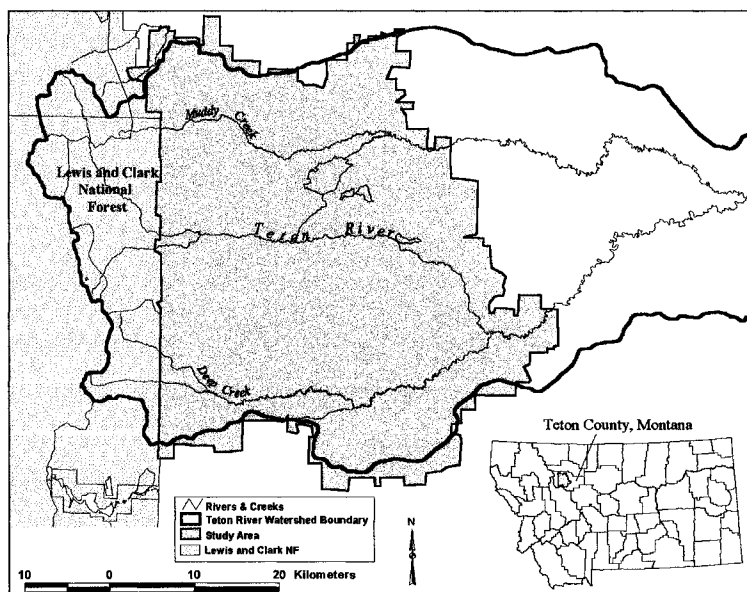


Figure 5.1. Study area location in North-central Montana.

METHODS

Data Layers and Retrieval

The jurisdictional and ecological base data were obtained from the United States Geologic Survey (USGS, 2001) and the Montana Natural Resource Information System (NRIS, 1999). Public ownership, hydrography, and county boundary data formed the base map within ArcView (NRIS, 1999). Metadata records are complete for these base map layers (NRIS, 1999). Metadata are systematic records detailing the origin of a particular dataset, data accuracy, and any methods that may have been used to process data for GIS applications. Metadata provide the public with an official and standardized means to evaluate the accuracy of data and ensure that data are used at appropriate scales and for appropriate analysis.

We obtained private property ownership polygons and ownership names for the study area from the Computer Assisted Mass Appraisal database from the Montana Department of Revenue (Montana Department of Revenue, 2001). These revenue data were built upon the United States Department of Interior's Bureau of Land Management's Geographic Coordinate Database.

Eighty Digital Orthophoto Quarter Quadrangles (DOQQ) were obtained from the Natural Resource Conservation Service office in Bozeman, Montana. These DOQQ or rectified digital aerial photographs were created by the United States Geologic Survey throughout the mid 1990s and consist of high resolution, 1:24,000-scale aerial photographic quarter quadrangles that cover the study area. Digital orthophoto quarter quadrangles are approximately 41 megabytes in size.

Data Compilation

The Montana Department of Revenue's land ownership data were provided as individual township blocks in ArcInfo coverage files. To view and query these data for the project area as one seamless database, we merged data sets using property geocode as the common field. This enabled us to readily query any parcel in the study area, determine ownership status, and then highlight the boundaries so that a participant could locate their parcels within the study area.

Selection of Participants

We focused our interactive mapping on the livestock management practices of cattle and sheep ranchers, outfitters, guest ranchers, hobby ranchers, and a honey producer. We have used the term "livestock related land user" (LRLU) to include livestock producers, outfitters, guest ranchers, and hobby ranchers in our study area as all used various combinations of cattle, sheep, horses, pigs, and poultry in their operations. The State of Montana classifies bees as "livestock" so we included honey producers in our definition of livestock related land user categories.

We developed these categories using the databases and assistance of the Teton County Agricultural Extension Service to arrive at a study area population of 64 active livestock related land users. We conducted 61 interactive mapping sessions. We had one refusal and were unable to contact the remaining two livestock related land users. We crosschecked our census population list with the MT Fish, Wildlife and Parks (MFWP) Grizzly Bear Management Specialist and a local state legislator to ensure accuracy. We justified our census of livestock related land users since 90% of reported human-grizzly bear conflicts documented by MFWP from 1986-2001 were associated with livestock

related land users as defined above. In other words, we wanted to ensure that we collected detailed information from those land users who were having the majority of conflicts. Seventeen percent of reported human-grizzly bear conflicts from this same period were associated with beehives managed by the local honey producer and 73% were associated with cattle and sheep ranchers, outfitters, guest ranchers, and hobby ranchers. The 61 livestock related land users that were surveyed, either own, manage, or lease approximately 130,733 hectares in the study area. The total study area population of 64 active livestock related land users accounted for 134,048 hectares of the study area.

The Process of Interactive GIS Mapping

We were interested in documenting the spatial locations of bone yards (carcass dumps), calving and lambing areas, grazing pastures, suspected grizzly bear activity areas, and locations of suspected and verified human-grizzly bear conflicts. We also worked extensively with a local honey producer to digitize 72 beehive sites and to document damage histories by grizzly bears during interactive mapping sessions.

Participants were initially contacted by letters and phoned 5 to 7 days later to schedule voluntary mapping sessions. Pre-mapping data management included the creation of GIS themes that would be used to designate different point and polygon features with each participant. These were: 1) suspected grizzly bear activity areas 2) bone yards, 3) calving areas, 4) lambing areas, 5) spring pastures, 6) summer pastures 7) fall pastures, and 8) suspected and unreported grizzly bear conflicts. Ownership boundaries were highlighted using ArcView's legend editor and we familiarized ourselves with the parcels prior to interviews to obtain a cursory knowledge of pasture arrangement and dominant vegetation.

Prior to actual mapping, participants were asked about possible suspected and unreported conflicts with grizzly bears. We asked them about the type, date, and season of unreported conflicts in the past 16 years. We only used data from 10 years (1991-2001) as we felt that anything before this period would make the data too suspect to be useful. We first recorded the number of suspected conflicts that participants told us about without the use of the digital photographs. During mapping sessions we then asked participants to spatially locate the previously discussed conflicts on the orthophotos. We then recorded the number of any additional conflicts that were recalled due to using the orthophotos. This allowed us to record whether there was any difference in the total number of conflicts that participants remembered without and with the use of digital orthophotos. We were interested in whether participant memory recall was possibly improved by seeing prominent features or spatial cues on their property that may have been associated with past grizzly bear conflicts. If participants remembered additional conflicts once they saw the orthophotos, we recorded this as a possible example a “spatial cue” in aiding memory recall.

We started each mapping session by giving a participant a “virtual tour” of the study area by highlighting rivers, towns, and then “zooming in” to a participant’s home property. We then asked where they suspected the majority of grizzly bear activity occurred on their parcels. This type of opening put participants at ease and introduced them to working with the mouse and how to create and edit a polygon to control for accuracy. If a participant was new to computers, we had them draw several practice polygons to feel comfortable with digitizing. Additionally, we always drew the livestock management practice polygons or points at approximately 1:5,000-1:15,000

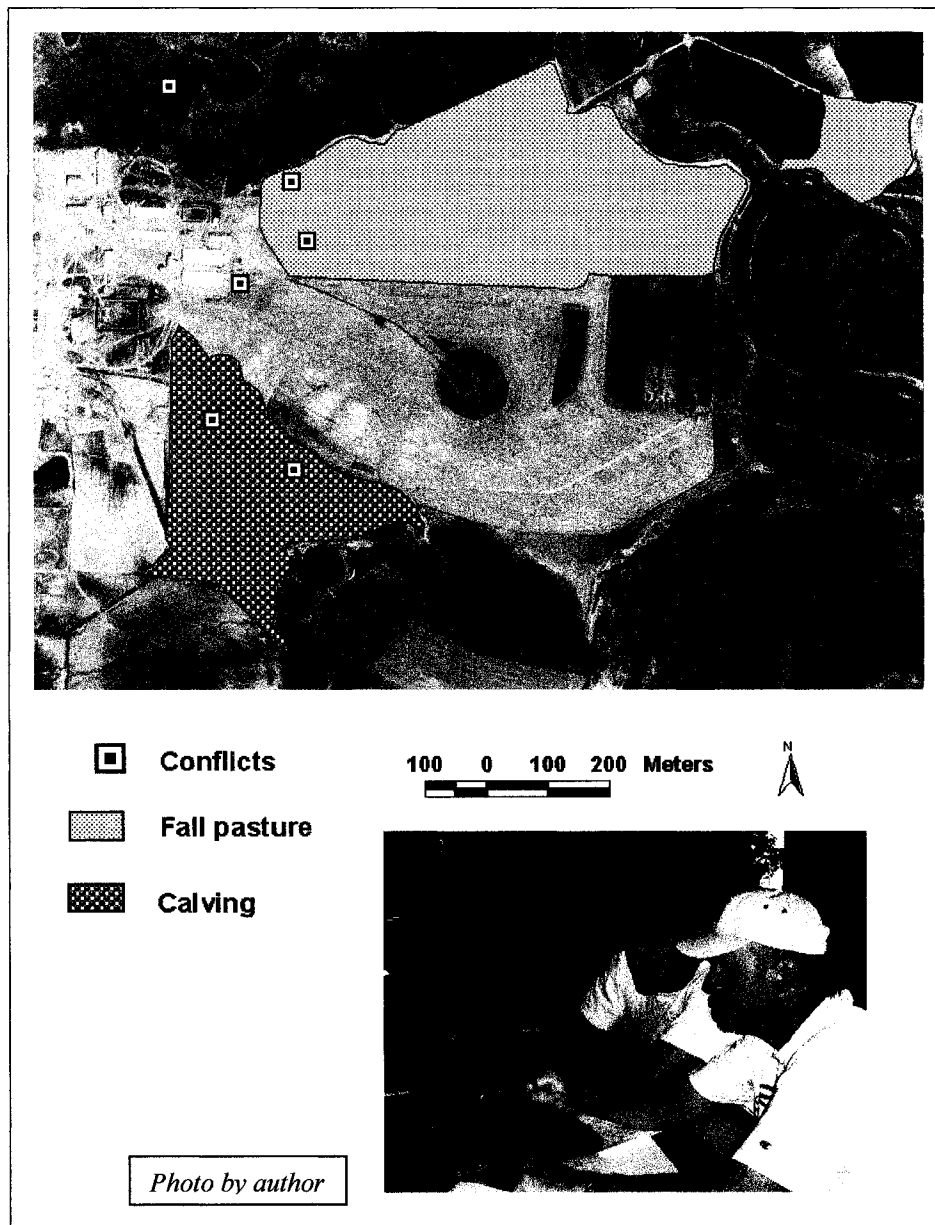


Figure 5.2. Example of interactive mapping with a schematic representing a typical livestock operation with suspected conflicts, fall pastures, and calving area using a high quality digital orththophoto.

scales. The high quality resolution of DOQQs revealed locations of corrals, barns, and even fence lines (Figure 5.2). If a participant did not wish to use the mouse to digitize land use practices, we had them gently trace land use practice polygons on the laptop screen with a pointer while we followed with the cursor. We used the same protocol with

the local honey producer to digitize 72 registered beehive site locations throughout the study area. While we mapped beehive sites, we used ArcView's database table editing function to build a protection status and "damage history" for each beehive site. During mapping sessions, we collected information on when each beehive site was established, season of use, dates of possible damage, and if the site had electric fencing to deter bears. Post-mapping data management involved editing themes, printing hard copy maps, and backing up all data onto compact disks and 100MB flashcards.

All mapping sessions were tape recorded and professionally transcribed. We used content analysis to measure participant responses to interactive mapping and documented positive, negative, and neutral verbal reactions during the mapping experience (Babbie, 1989).

Field Trials

The data collection technique described above went through an extensive and iterative, pre-testing process to ensure functionality and reliability. For the pretest, we worked with a total of 15 participants in separate locations in western Montana so as not to bias participants in the study area. The pre-testing process allowed us to determine how comfortable participants would be with the technology and how much time it would take to digitize land use practices. Pre-testing also allowed us to evaluate laptop battery life and to test efficacy of an Intellimouse[®], a laser optic mouse, in field settings.

RESULTS

Interactive Mapping Sessions

Participants were cooperative and inquisitive during our one-on-one interactive mapping sessions. We conducted 61 of a possible 64 mapping sessions for a response rate of 95%. We had one refusal and could not contact the other two landowners. Based on our content analysis we found that the majority of participants (75%) were positive about the process of producing data on their livestock management practices through interactive mapping. It was evident that participants were able to readily explain their management practices with the aid of maps. For example, as we located calving or lambing areas, participants often told us why they had chosen specific pastures for their livestock or why they had chosen a portion of their ranch for carcass disposal. It was evident that interactive mapping helped us produce spatial datasets that included underlying explanations by the participants who helped generate them and led to other insights regarding management practices. Comments from participants about the mapping experience were volunteered during and after mapping sessions.

Additionally, scale issues were readily accounted for using the medium of GIS. Thirty percent of the participants had parcels larger than 2,000 hectares and using hard copy maps would have been cumbersome at these scales. Interactive mapping allowed us to systematically cover the entire ranch parcel at different resolutions. Ten participants told us during sessions that hard copy maps made from the digital aerial photographs would be particularly useful for improving their ranch management. These participants explained that they would like to provide maps for their field hands to assist them with navigating on their ranches and for alerting them to stream and river bottom areas that

experience heavy grizzly bear use. Of these ten participants one expressed interest in having vegetative maps of preferred grizzly bear foods for their property so they could adjust the timing and location of spring grazing to minimize frequency of contact between their livestock and grizzly bears.

Approximately 30% of the participants were sufficiently comfortable with the technology to complete all mapping polygons and point locations on their own when assisted throughout the interviews with editing, saving, and using the correct drawing tools in ArcView. Mapping allowed us to update landownership or lease information during interviews. The mean completion time for interactive mapping sessions was 39 minutes. The minimum and maximum times taken for mapping were 20 minutes and 120 minutes respectively.

We also found that 10% of participants remembered additional grizzly bear conflicts when they were asked to locate suspected grizzly bear conflicts on the digital orthophotos. This suggests that spatial cuing may have helped to jog memories of additional grizzly bear conflicts for those participants when they were exposed to the orthophotos of their properties. Additionally, more than 70% of the participants actively used the digital orthophotos to help describe the spatial context of suspected conflicts to us. For example, it was common for participants to provide details about the vegetation and topography that we were looking at in the digital orthophoto and relate that to the suspected grizzly bear conflict in question.

Mapping sessions with the local honey producer were productive because the high quality digital orthophotos revealed beehive locations in the study area (Fig.5.3). “Real time” database entry to record the histories of beehive damage and hive protection status

also went efficiently using the table function and split screen option in ArcView to collect these data.

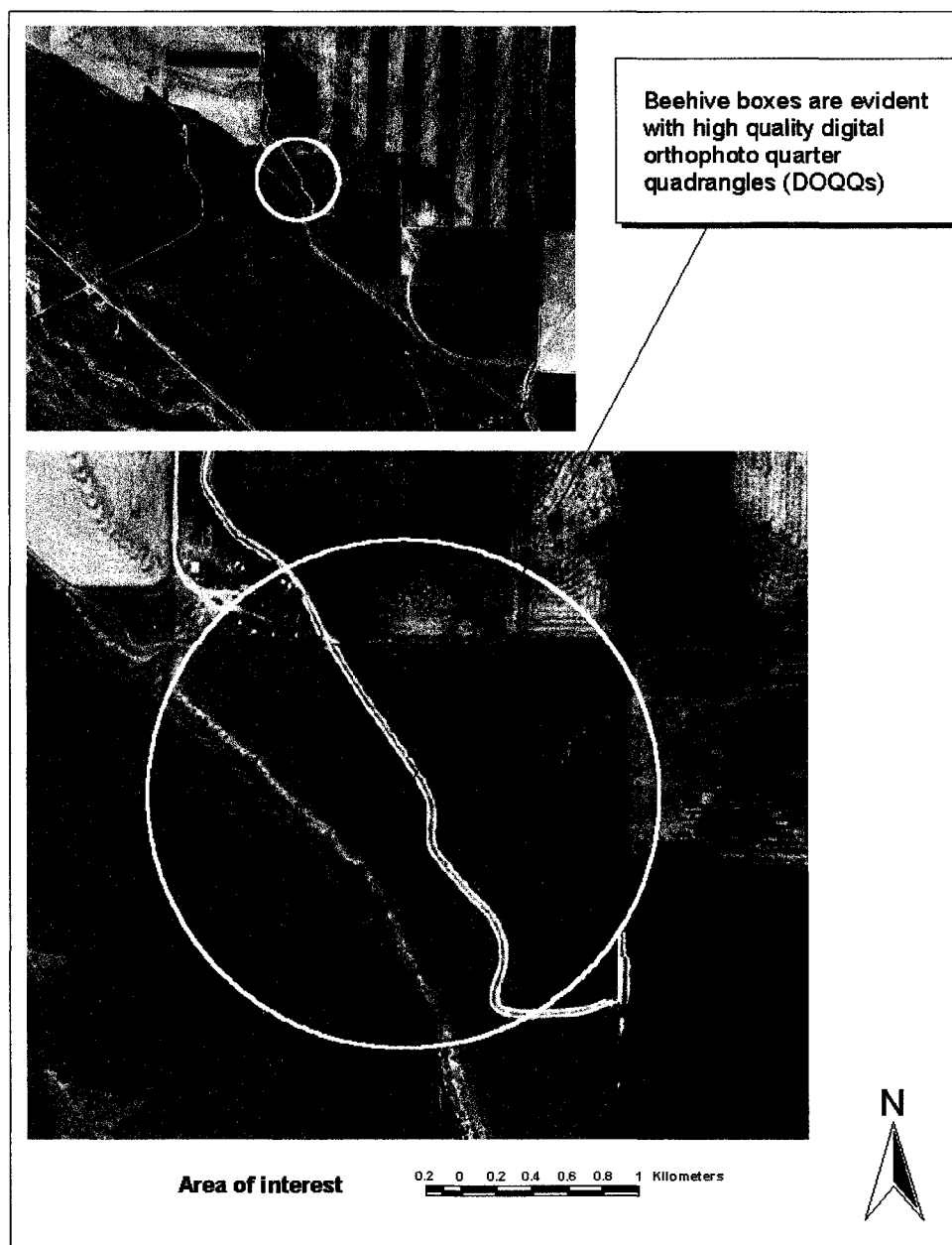


Figure 5.3. High quality resolution of digital aerial orthophotos allows beehive site locations to be interactively mapped. Note the access road in the upper left corner of the yellow circle to beehive boxes. The beehives are below the irrigation ditch in the middle of the yellow circle.

Computer Performance

Our laptop was configured to maximize hard drive space, speed, and screen size. The hard drive held 20 gigabytes and the laptop has a Pentium III processor and 164 megabytes of RAM. The large screen size (15" LCD) was invaluable for easy viewing with participants. We also used a direct current converter so that the laptop battery could be charged from a cigarette lighter in field vehicles and carried a spare battery for emergencies. A Microsoft Intellimouse that used an infrared laser optic to track instead of a roller ball was crucial for this study. We were able to use our pant leg or any semi-smooth surface to easily move the cursor when interactively mapping in field settings.

DISCUSSION

We recommend our interactive mapping technique to wildlife and conservation professionals who have a familiarity with GIS and the need to collect or display spatial data for their research, management, or conservation objectives. The widespread availability of digital geographic data from state and federal agencies throughout the United States makes data retrieval and compilation practical and cost effective. Our methods may be especially appropriate for conservationists who work in the field with rural residents and need quality data sets that occur on private property. Interactive mapping is an efficient means of stimulating non-threatening dialogue with livestock related land users, collecting data, can enhance data quality, and is a powerful learning tool.

When we started this project, we were concerned that our approach might be met with suspicion and distrust when participants were presented with high quality maps of their private property. The high response rate (95%) and positive responses expressed by

participants (75%) was encouraging. We found that interactive mapping is a productive technique to produce high quality data and creates meaningful dialogue regarding sensitive issues like grizzly bear-human conflicts. The visual backdrop of the digital orthophotos provided participants with the means to explain their management practices within a spatial context. We speculate that participant cooperation and enthusiasm with interactive mapping is in part an outcome of seeing the results of their labor. Freshly cut hay, pivot irrigation systems, and grain elevators are personal landmarks that elicit a sense of accomplishment and pride for participants. Additionally we suspect that the high response rate and interest shown by participants in mapping may be due to participants' prior exposure to hard copy maps. Many ranchers and farmers throughout the western United States who have participated in the Conservation Reserve Program and other farm assistance programs are not intimidated by maps of their private property and understand the need to accurately delineated acreages to qualify for specific programs. Yet when we started this project, we did not know exactly how our questions about and desire to map livestock management and beehive management would be received. High quality orthophotos can reveal much about a person's operation and we were concerned that some might feel that that a "high tech" approach was intrusive. However we feel that our technique and the use of GIS technology may help build trust between the agricultural community, researchers, and wildlife managers through the interactive process of map learning (Thorndyke and Stasz, 1980). Interactive mapping reverses the traditional flow of information that typically originates from wildlife experts and allows participants to explain the spatial context of their management practices and conflicts with respect to grizzly bears. For example, we were pleased that participants

expressed an interest in minimizing human-bear contact through the use of maps to avoid grizzly bear activity areas. Insights like those above only occurred because of the interactive map learning process. Additionally, the active use of the maps by more than 70% of the participants to describe the nature of suspected grizzly bear conflicts can provide insights to researchers and managers. For example, several ranchers during interactive mapping sessions showed us where grizzly bears use their irrigation ditches to move on their ranch property or where grizzly bears had day beds on their property. The management and research community may benefit from using our techniques to elicit local knowledge about grizzly bear habitat use and activity on private lands. We have found that livestock related land users are intimately familiar with their lands and are keenly aware of grizzly bear use—soliciting information from “the ground up” may be a worthwhile approach for actively engaging rural residents with grizzly bear management objectives. In essence, this approach may cause rural residents to feel that their input and knowledge matters—a foundation that can only help build trust among those involved in grizzly bear recovery. Berkes and Folke (1998) provide several excellent examples that explore the value of indigenous knowledge to natural resource management decisions.

Our methods can be used for applications where spatial or land use information can readily be displayed in digital map form for use among managers, researchers, and local communities (Cornett, 1994). Some applications might include invasive plant mapping and monitoring, wolf-livestock conflicts, human-elephant conflicts, and even aquatic ecosystems (Tawake et al., 2001).

Our finding that 10% of the participants remembered additional conflicts may be attributed to spatial cuing when they saw particular landmarks on their properties that

triggered memory recall. This finding is consistent with other researchers who have repeatedly found that spatial cues from maps enhance memory recall (McNamara et al., 1992). Scientists have also demonstrated that cues in the same region of a spatial layout prime each other (McNamara et al., 1989). These phenomena may help explain why participants remembered additional conflicts when they were presented with high quality maps that may serve to cue memory recall via distinct places on their property where chronic conflicts have occurred. Thus, as found elsewhere, interactive mapping helped us gather more accurate data and demonstrates the importance of spatial cues during map learning (MacEachren, 1992).

CONCLUSIONS

We recommend the use of interactive mapping as a data collection technique, as a method to engage livestock related land users in productive dialogue about their land use practices with the aid of maps, and as a means to improve grizzly bear management. Limitations associated with our methods include the costs of laptop computers and GIS training. Many wildlife agencies and conservation organizations may not want to expend precious budgetary dollars on machines that can range from \$1,500 to \$4,000.. Geographic Information System software training can be expensive, ranging from hundreds to thousands of dollars depending on the types and lengths of courses (Environmental Systems Research Institute, 2002). We recommend that interested managers, conservationists, or natural resource professionals have some general working knowledge of GIS prior to attempting the types of data acquisition, manipulation, and collection we describe here. We recommend that interested persons without a GIS

foundation start by taking one of Environmental Systems Research Institute (ESRI) week-long courses to teach basic GIS skills.

Our success with interactive mapping should be tempered by the possibility that some people may find the technology and data sets used in this method as an intrusive breach of privacy. This did not occur to us during our study, but we merely wish to make the cautionary point that people could react to this type of data collection with distrust if they are not clearly informed about the goals and objectives of the study or work at the outset. When we initially contacted potential participants with introductory letters and follow-up phone calls, we clearly indicated that we would be using computers and asking for help in co-generating data. Moreover, success with this technique will also depend on how well a researcher or natural resource professional communicates and works with people on a one-on-one basis.

Applications to other regions in the United States and other countries will depend on available data, data quality, and initial investment costs in computers and training. Despite these potential limitations, our methods have broad applicability for conservation at multiple landscape scales with multiple species.

CHAPTER 6: LANDSCAPE FEATURES, ATTRACTANTS, AND CONFLICT HOTSPOTS: A SPATIAL ANALYSIS OF HUMAN-GRIZZLY BEAR CONFLICTS ON PRIVATE AGRICULTURAL LANDS

ABSTRACT

We identified and analyzed landscape features and agricultural related attractants that predispose grizzly bears to risk of conflicts with human activities on private lands in Montana. Low elevation private lands are critical seasonal habitat for grizzly bears in portions of Montana. The overlap of grizzly bears and livestock often lead to conflicts and in cases the removal of grizzlies from local populations. Our analysis focused on determining how the spatial locations of rivers and creeks, livestock pastures, bone yards, beehives, and grizzly bear habitat were associated with reported grizzly bear conflicts from 1986-2001. We based our analysis on a survey of 61 of a possible 64 livestock producers in a defined study area in Teton County, Montana. With the assistance of livestock and honey producers, we mapped the locations of cattle and sheep pastures, bone yards (carcass dumps), and beehives. We also incorporated remotely sensed thematic mapper images and digital orthophotos for vegetation in the study area and reported grizzly-bear human conflict locations (1986-2001) from Montana Department of Fish, Wildlife and Parks (MFWP). Through density surface mapping, we identified independent clusters of conflicts that occurred seasonally. We have termed these conflict hotspots. The conflict hotspots we identified accounted for 75% of all conflicts during 1986-2001. We describe the types of landscape features and attractants associated with conflict hotspots and subsequently tested how these factors affected the probability of conflict. We found through Monte Carlo (MC) simulations, that conflicts were strongly associated with rivers and creeks. Sheep lambing areas and spring and summer sheep pastures were also strongly associated with conflict locations. Cattle calving areas,

spring cow/calf pastures, fall pastures, and bone yards were also associated with conflicts. Our MC simulations to test if beehive protection status was associated with conflicts were inconclusive. However a chi-square test suggested that protected (fenced) beehives were less likely to experience conflicts than unprotected beehives. Conflicts occurred at a higher rate in riparian and wetland associated vegetation than would be expected under an assumption of spatial randomness. We discuss the complexity and interrelationships among these salient factors.

INTRODUCTION

Population viability and mortality risks to grizzly bears are important components to grizzly bear recovery since human-grizzly bear conflicts are often a precursor to mortality. Mattson et al., (1996:134) suggested that, "There is little doubt that the current persistence of grizzly bears at lower latitudes is largely determined by human predation, modified by the effects of food abundance on recruitment." In southern Canada and the United States, from 1974 to 1996, 85% of known bear mortality was attributed to humans (Mattson et al. 1996). The U.S. Fish and Wildlife Service suggest that minimizing bear mortality, specifically adult females, is one of the most important challenges of maintaining small, threatened populations of grizzlies (U.S. Fish and Wildlife Service, 1993.) In Montana, researchers and managers have called for a reduction in the availability of anthropogenic food sources and attractants on privately owned lands to reduce conflicts and mortalities particularly for female grizzly bears (Mace and Waller, 1998; Madel 1996). The interactions among grizzly bears and humans on private agricultural lands and the spatial conditions and related factors that predispose grizzly bears to risk of conflicts have not been thoroughly explored.

PURPOSE OF SPATIAL ANALYSIS

Our research focused on the intersection of ecological and social factors that contribute to human-grizzly bear conflicts on private agricultural lands. Specifically, we explored the spatial associations among reported human-grizzly bear conflicts, landscape features, and attractants related to livestock and honey production in Teton County, Montana, USA. We were particularly interested in understanding how the spatial distribution of conflicts might be affected by human land uses. We address two main questions. What is the spatial context of human-grizzly bear conflicts with respect to landscape features and agricultural related attractants in the study area? Are these features and attractants associated with an increased probability of conflict?

Throughout this chapter, we use the terms landscape features and attractants. Landscape features refer to rivers, creeks, and/or riparian and wetland associated vegetation and attractants refers to the locations of seasonal livestock pastures, bone yards (carcass dumps), and/or beehives. Since the study area is dominated by agriculture and has a history of extensive bear use, we wanted to establish the relative spatial associations among landscape features, attractants, and the likelihood of conflicts by focusing on the locations and management of cattle, sheep, and beehives (Aune and Kasworm 1989; Madel 1996).

The data set we used on reported human-grizzly bear conflicts contained information on different types of conflicts that had not been spatially analyzed. We acknowledge that knowing about the type of conflict is relevant for describing general categories of conflicts, but does not necessarily help explain the scale, location, or spatial patterns that are influenced by landscape features and attractants. Additionally, there are

similar landscapes throughout Montana and Wyoming where grizzly bears are reoccupying former habitats that are dominated by agricultural land uses. This analysis may provide management guidance to evaluate the spatial context of conflicts in other areas with bears, but with poorer historical records on conflicts, and may help evaluate where future conflict risk areas might be as bears make use of these habitats.

To answer our first research question about the spatial context of conflicts, we have defined, identified, and described discrete clusters of conflicts or what we term “conflict hotspots.” This will enable us to: 1) illustrate the time-specific or seasonal differences in conflict hotspot locations, 2) describe the apparent chronic nature or longevity of hotspots as a locus of conflicts for grizzly bears, 3) describe the types of conflicts associated with hotspots, 4) determine the scale at which the majority of human-grizzly bear conflicts occur, 5) provide a means to visually display and describe landscape features and attractants that are associated with seasonal conflict hotspots, 6) identify areas with landscape features and attractants that do not have chronic conflicts, and 7) evaluate whether hotspots are areas that lead to problems for bears or if hotspots are simply a product of relatively few “problem” bears.

To answer our second question, we relied on a series of univariate analyses to quantify the spatial associations of landscape features and attractants primarily through evaluation of the differential distances of observed conflicts to a specified feature or attractant compared to a random distribution of points. Our rationale was to in part, to test whether the locations of conflicts we observed in conflict hotspots were spatially random or had an underlying structure that was a function of both specific landscape features and attractants that were available to grizzly bears. Additionally, the univariate

analyses were useful for exploratory purposes in logistic regression model selection efforts found in Chapter 7.

STUDY AREA

The study area is located in north-central Montana's Teton County. We selected this study site because of the concentration of grizzly bears that make extensive use of privately owned and managed agricultural lands. Because our research focuses on private lands, we bounded the study area on the west using the Lewis and Clark National Forest boundary and on the east using the rough transition of rest-rotation cattle ranches to intensive winter wheat farms. The north and south boundaries of the study area were based on the Teton River watershed. The study area is approximately 172,000 ha or 1,720 km² (Figure 6.1). Approximately 80% of grizzly bear spring habitat in this area is found on private lands primarily in fen and riparian habitats (Aune and Kasworm 1989). The riparian areas used by grizzly bears provide critical seasonal foraging opportunities, cover, and secure habitats for movement and life history requirements (Aune and Kasworm 1989).

The 61 livestock related land users that were surveyed own, manage, or lease approximately 130,733 ha (\approx 97%) of the study area that is available for agriculture (\approx 134,000 ha). Ranches tend to be located along creek and river bottoms in this area and unsecured attractants like calving afterbirth, calves, lambs, beehives, are easily found by grizzly bears. The concentration of bear use in these areas has resulted in large numbers of human-grizzly bear conflicts in the form of cattle depredation and property damage (Madel 1996).

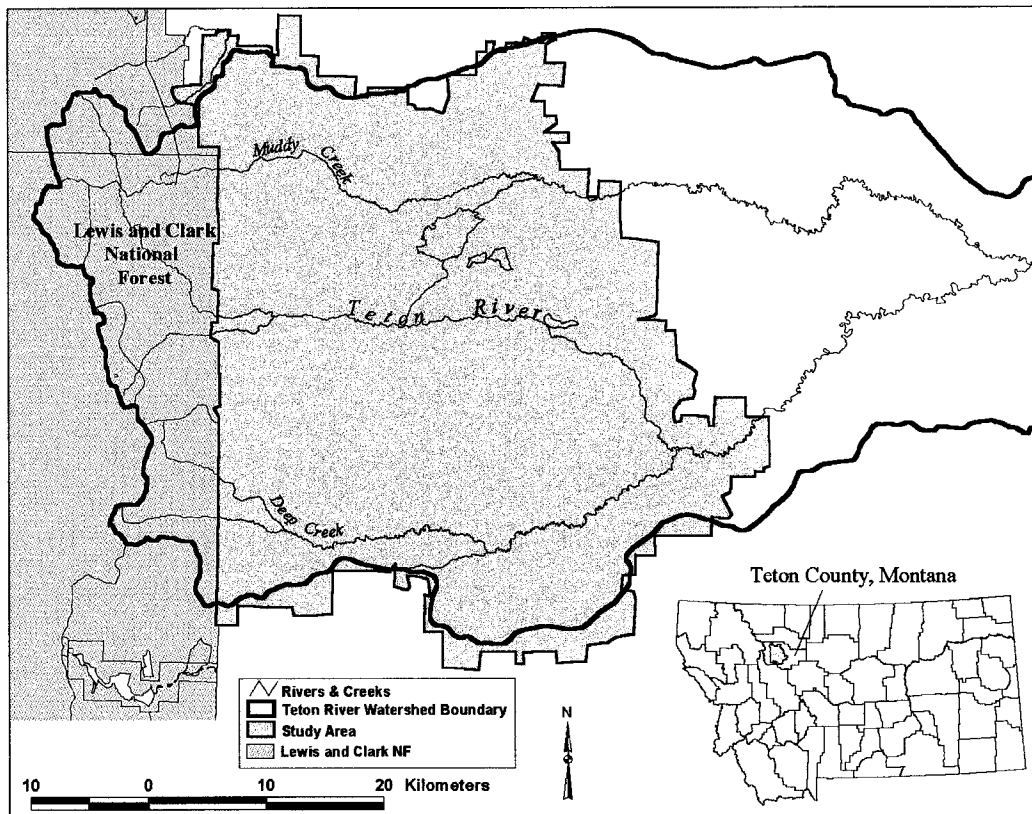


Figure 6.1. Study Area location in North-central Montana.

METHODS

We made use of Geographic Information System (GIS) methods for data collection, analysis, and graphical display of data. We used GIS for density mapping of conflict hotspots and we developed customized Arc Macro Language (AML) scripts for Monte Carlo (MC) simulations. Additionally, we used an assortment of different database and statistical software for specific statistical tests. In the following sections, we discuss the sources and development of data layers used for analysis and then we describe the specific definitions and methods we used for density mapping of conflict hotspots, MC simulations of river and creek data, livestock management data, and beehive data. Additionally, we describe methods used for chi-square tests of beehive

protection status, and a Z-test to determine the use of riparian and wetland associated vegetation by grizzly bears given this cover type's availability in the study area.

Sources and Development of Data Layers

Reported Human-Grizzly Bear Conflict Data

A data set on reported human-grizzly bear conflicts within our study area boundary ($n=178$) from 1986-2001 was shared with us by Montana Department of Fish, Wildlife and Parks (MFWP). Problems between humans and grizzly bears cover a spectrum—from livestock depredations, beehive damage, to close proximity incidents where a grizzly bear may have been near a residence. We use the term “human-grizzly bear conflict” or simply “conflict” to refer to any incidents that have been reported to MFWP and is part of the data set. MFWP collected various information for each conflict and data that were relevant to this study included: 1) calendar date of conflict, 2) location of conflict [Universal Transverse Mercator (UTM) coordinates], 3) type of conflict, and 4) identity of grizzly bear, if known. All locations were reviewed with MFWP for accuracy prior to analysis. The MFWP bear management specialist responded to 91% of reported conflicts calls from 1986-2001. The specialist was consistent in recording UTM locations of conflicts and has extensive knowledge of the study area topography from more than 20 years of field experience. Moreover, since this one specialist responded to an overwhelming majority of conflicts, possible errors or bias associated with locating UTM coordinates or response effort was systematic compared to the possibility of having multiple individuals responding and recording conflict locations.

River and Creek Data

We used a digital vector-based hydrography layer at 1:100,000 scale to represent rivers and perennial creeks in the study area (NRIS, 2001). Metadata records can be obtained at the Montana Natural Resource Information System (NRIS) database (2001). Metadata are systematic records detailing the origin of a particular dataset, data accuracy, and any methods that may have been used to process data for GIS applications. Metadata provide the public with an official and standardized means to evaluate the accuracy of data and ensure that data are used at appropriate scales and for appropriate analysis.

Livestock Management Data

Our study area contained 64 total livestock related land users. We surveyed all except three (95% response rate). We had one refusal and were unable to contact the remaining two. We use the term “livestock related land user” to include cattle and sheep ranchers, outfitters, guest ranchers, and hobby ranchers as all used various combinations of cattle, sheep, horses, pigs, and poultry in their operations. The State of Montana classifies bees as “livestock,” so we included honey producers in our definition of these livestock related land user categories. We justified our focus on livestock related land users since 90% of reported human-grizzly bear conflicts documented by MFWP from 1986-2001 were located on lands either owned, leased, or managed by livestock related land users as defined above.

Using a GIS interactive mapping technique we collected information on the general seasonal locations of cattle and sheep pastures, locations of bone yards (managed and unmanaged), and locations and protection status (fenced or unfenced) of beehives within the study area for 1986-2001. For the purposes of this exploratory and descriptive

analysis, we did not distinguish between “managed” and “unmanaged” bone yards in density mapping or univariate statistical tests (see footnote in Table 6.9 for rationale). Managed bone yards were those where carcasses were picked up by MFWP relocated to remote portions of the area. Unmanaged bone yards were those where carcasses were left to decompose. We did attempt to account for differences in beehive protection status. Of the 61 livestock related land users who provided data on management practices, 11 ranches had changed ownership or lease status during the 16-year study time frame. We collected information from previous owners and managers for these 11 ranches and included the cattle and sheep data from these ranches in the Monte Carlo analysis. We found that 10 of the 11 ranches stayed in ranching and that current livestock management patterns were similar to those of previous owners or lessees. This reduced the likelihood of errors that could occur if a conflict was mismatched to management practices because of changes in practices associated with changes in ownership or lease status.

Beehive Data

The local honey producer assisted us in locating and mapping beehive sites in the study area. For each site, we recorded the year the beehive was established, season of use, and the year it was protected with an electric fence. All beehives within the study area were used for analysis.

Riparian & Wetland Associated Vegetative Data

We considered river and creek features to be a conservative indicator of hydrologic effects on conflicts because these linear landscape features do not wholly account for riparian and wetland associated vegetation. Riparian and wetland associated vegetation is an important component of grizzly bear habitat in the study area and we

were interested in determining how proportional use (treating conflict locations as a surrogate) of this vegetation compared to its proportional availability within the study area.

We used a digital, 30-m Landsat Thematic Mapper (TM) image of the current vegetation map of western Montana (Redmond, 1996) and photo interpretation of digital orthophoto quarter quads (DOQQ) of actual vegetation to delineate riparian and wetland associated vegetation for analysis. Digital orthophotos were obtained from the Natural Resource Conservation Service office in Bozeman, Montana. These aerial photographs were created by the United State Geologic Survey throughout the mid 1990s and are high resolution (1-m), 1:24,000-scale (USGS 2001). We used the following cover types from Redmond (1996) to digitize riparian and wetland associated vegetation (Table 6.1).

Table 6.1. Cover types of riparian and wetland associated vegetation along the Rocky Mountain Front.

<i>Code</i>	<i>Cover type</i>
6101	Needle leaf dominated riparian
6102	Broadleaf dominated riparian
6103	Needle leaf-broadleaf riparian
6104	Mixed riparian (trees + other)
6201	Grass-forb riparian/wetland
6202	Shrub riparian/wetland
6203	Mixed grass-forb-shrub riparian
3201	Mesic upland shrubland
3202	Warm mesic shrubland
4102	Broadleaf forest
4221	Mixed mesic forest

Source: Redmond, R.L. 1996. Current vegetation map of northern Idaho and western MT. Wildlife Spatial Analysis Lab, MCWRU, The University of Montana, Missoula, MT.

These vegetative layers were selected in part because of intensive use by grizzly bears. Aune and Kasworm (1989) designated all private land in the Birch-Teton and Teton-Sun Grizzly Bear Management Units as spring habitat because of intensive spring use of riparian lowlands along rivers, creeks, fens, and wetlands. Both of these bear

management units are within the study area. Riparian cover class types 6101-6104 and 6201-6203 are associated predominantly with river and creek systems. Vegetation found in depressional wetlands, fens, and other hydric shrublands were included in our analysis (cover types 3201, 3202, 4102, and 4221). We considered vegetation associated with wetter sites to account for the elevational distribution of grizzly bears that Aune and Kasworm (1989) observed as a result of receding snowlines and plant phenology. Eighty percent (80%) of the radio locations ($n=2633$) that Aune and Kasworm recorded were below 2000 m and showed high fidelity to riparian and wetland lowlands. The broadleaf forest (code 4102) and mixed mesic (code 4221) cover classes were also included in the riparian and wetland associated vegetation layer to capture wetter forest types associated with but not necessarily components of riverine features.

We digitized all riparian and wetland associated vegetation using photo interpretation of digital orthophotos to correct errors in the TM-based vegetation maps. There were fields with pivot, ditch, and flood irrigation in small portions of the study area. In some cases, these irrigated fields were classified as riparian cover types, specifically 6202 (shrub riparian/wetland) and 6203 (mixed grass-forb-shrub riparian).

Operational Definitions for Conflict Hotspots

To systematically identify and describe what appear to be discrete clusters of conflicts throughout the study area, we needed to operationally define an analytical construct to develop our concept of a hotspot. Since repeated human-grizzly bear conflicts can lead to grizzly bear relocations and or removals out of the population by wildlife management agencies or through illegal killing, we wanted to identify areas that pose conflict and potential mortality risks to bears. Specifically, we wanted to delineate

and describe specific areas in the landscape that were characterized by independent clusters of conflicts, where grizzly bears and humans were consistently coming into contact. Thus, a hotspot represents a locus point where there is an increased concentration of conflicts among humans and grizzly bears compared to other contexts in the study area.

The Interagency Grizzly Bear Guidelines (IGBC) is a detailed grizzly bear management framework that provides a decision-making structure for managers across agencies and jurisdictional boundaries in the United States. These guidelines set out a systematic method for determining "nuisance" bear status and ultimately determine the fate of individual grizzly bears that come into repeated contact with people. Depending on the sex and age class of an individual bear, and the number and condition (type) of human-grizzly bear conflicts, nuisance status is determined and management actions follow (IGBC, 1986). Our goal of identifying hotspots is to guide management and conservation efforts to specific contexts where repeated conflicts among humans and bears will most likely lead to bears being classified as a "nuisance" and potentially be relocated or removed from the population. Frequency of contact among grizzly bears and humans is a key component for understanding the specific conditions that lead to human-caused mortality (Mattson et al., 1996).

We based our hotspot definitions on two general concepts: 1) numbers of conflicts that occurred in distinct clusters and 2) the number of years that conflicts occurred in these clusters. Thus, a hotspot was defined in part, as a density surface area with at least 3 conflicts based on a moving window analysis of 50-m grid cells within a 1.6 km search radius (rationale discussed below). The second part of the hotspot definition deals with

time. Places that may have had several conflicts but only over a short period of time, say months or during one year, probably do not constitute a true problem area. Individual bear behavior, habitat conditions (it might be poor), or a reaction to the incident by those involved to prevent future conflicts, might stop this situation from becoming a true hotspot. Places where conflicts occur for at least 2 years (in total) would suggest that human behaviors coupled with site-specific habitat conditions are in part responsible for making attractants consistently available to bears. Two years is a reasonable "temporal benchmark" that represents repeated interactions and assumes some degree of continuity of human activities that lead to repeated conflicts. A Spearman's rank order correlation test was conducted to determine if the total number of conflicts found in a hotspot was related to the number of years that a hotspot had conflicts.

Chronic and Non-Chronic Hotspots

Once we identified hotspots that had at least 3 conflicts for at least 2 years (in total), we wanted to further refine our hotspot analysis and establish a time threshold to separate those hotspots that were "chronic" with those that were "non-chronic." We defined *chronic hotspots* as those with at least 4 years of conflicts and *non-chronic hotspots* as those with less than 4 years (in total) of conflict. Our goal was to identify those chronic hotspots that were most likely to lead to repeated problems for bears over time and focus attention to contexts in the landscape where management efforts should be concentrated.

We recognize that these are normative, a priori constructs that are subjective in nature. However, we felt that some type of definitions were necessary so that we could systematically identify particular contexts in the study area where conflicts consistently

occurred. Furthermore, since we used a fairly liberal definition for our initial identification of hotspots and further refined our analysis to chronic versus non-chronic hotspots, we have provided managers with the option of prioritizing their management efforts on chronic hotspots, while still maintaining the complete picture that included non-chronic hotspots.

Mapping and Identification of Hotspots

We normalized the conflict data by season prior to generate density surface maps. Spring, summer, and fall were classified into the following time lengths: 4.5 months, 2 months, and 1.5 months based on their annual availability. These corresponding weights ($1/4.5$, $1/2$, and $1/1.5$) were then applied to the grid cells for each seasonal density map resulting in a map of conflicts density per month. For example, spring had 93 conflicts during 1986-2001 or 20.66 conflicts/mo. ($1/4.5 \times 93$). Seasonal conflict density maps were made to demarcate potential candidate hotspots and to compare hotspots locations across seasons. A moving window using a 1.6 km search radius was used to delineate the continuous surface density of hotspots. We then identified hotspots that had at least 3 conflicts on a density surface and had at least 2 years (in total) of conflict occurrence. Seasonal density maps had different density intervals that corresponded to at least 3 conflicts within the 1.6 km search radius and served as a threshold for hotspot identification.

We chose a search radius of 1.6 km based on the recommendation of researchers from southern Alberta (Gibeau 2000; Gibeau et al. 2002). These researchers found daily movement distances based on 4 years (across seasons) of intensive radio telemetry work on female grizzly bears ($n=17$) using 385 daily movement distances. We used the

average distance moved by female grizzly bears with cubs over a 24-hour period, taking the mean of when people were active (1.3 km; 08:00-17:00) versus inactive (1.9 km; 17:00-08:00) as a single estimate of daily movement. There were no daily movement data for grizzly bears on the Rocky Mountain Front, so we used data from the most similar ecosystem available to derive a biologically meaningful search radius. Conditions that affect the probability of conflict likely operate at several scales, including the lifetimes, years, and seasons for individual bears. However, Mattson (per. comm. October 18, 2002) has suggested that features encountered by bears during 24-hr to 48-hr foraging bouts may have the greatest influence on the likelihood of conflict. In Yellowstone National Park this is roughly 9 km² (Schleyer et al. 1984, Haroldson & Mattson, 1985). A 1.6 km search radius results in an 8 km² circular area.

Monte Carlo Methods

Monte Carlo (MC) methods refer generally to procedures where samples of randomized distributions are simulated or processed for comparison with some observed phenomena (Manly, 1997). MC methods are particularly useful with spatial data when observations appear to have an underlying structure that may not be due to chance alone. Simulating the likelihood that a random distribution would fit the same pattern as the observations is a means of quantifying the probability of an event given that the observations occurred at random. The use of MC simulations in this analysis was to univariately assess the relative strength of spatial association or patterns among different landscape features and attractant locations with the locations of human-grizzly bear conflicts.

River and Creek Data

We measured the distance of all conflicts ($n=178$) to the nearest river or creek using an ArcView Nearest Neighbor Extension v. 3.5 (Jennes, 2001). We compared the observed distribution of distances to a distribution based on 1000 random locations of 178 points, each (Manly, 1997; McKenney et al., 2002). For each of the 1000 iterations we calculated the distance of the 178 random points to the nearest river or creek (Jennes, 2002). From this, we calculated the mean and median distance for each random distribution. We then calculated the number of averages and medians from random distributions that were greater than the observed mean and median, computed the MC p-value, and 95% confidence intervals. For example, if 995 random distribution averages and medians out of 1000 were greater than then observed mean and median, the p-value = 0.005. This protocol was used for all subsequent Monte Carlo tests, described below, with some changes to sample size and measurement methods.

Livestock Management Data

Using an ArcView Nearest Neighbor Extension (Jennes, 2001), we measured the linear distance of conflicts to the nearest following features: 1) calving and lambing area(s) centroids (center of polygon), 2) cattle and sheep spring pasture(s) centroids, 3) cattle and sheep summer pasture(s) centroids, 4) cattle and sheep fall pasture(s) centroids, 5) aggregated calving and lambing area centroids, and 6) bone yards. If a conflict point fell within a specified feature like a calving area polygon, we assigned a distance of zero to that point. This same protocol was used during MC simulations for random points.

Numbers of conflicts used in MC simulations varied by the number of conflicts that occurred in each season to account for changes of grazing locations and grizzly bear

use. We grouped conflicts into the following seasons: Spring =den/den vicinity emergence to July 15, Summer =July 16 to September 15, and Fall =September 16 to denning based on changes in grizzly bear diets (Craighead et al. 1982; Mace and Jonkel 1983). These seasonal intervals overlapped with seasonal changes in livestock pasture locations. Based on interactive mapping sessions with livestock related land users and discussions with the Teton County Extension Agent, we found that cattle and sheep pasture locations had generally been used for seasonal or time-controlled grazing over the 16-year study time frame (D. Clark, per. comm. May 19, 2003). While resting and rotating pastures occurs, we asked livestock related land users to identify the general pasture locations that they traditionally used for spring, summer, and fall pastures during 1986-2001. For analysis purposes, we made the assumption that these pasture locations were generally stable despite site-specific changes in livestock pasture locations that might occur due to changes in forage quality, periodic drought, changes in herd size, etc. The Teton County Extension Agent also indicated that cattle calving areas, spring cattle pastures for cow/calf pairs, lambing areas, and spring sheep pastures for ewe/lamb pairs were the most spatially stable pasture locations since these were located in close proximity to the ranching facilities in order for producers to oversee the calving and lambing process during the early spring (D. Clark, per. comm. May 19, 2003). Additionally, there were instances where livestock producers only used summer grazing pastures annually since they calved outside the study area. And there were instances where producers only calved and used spring pastures annually inside the study area but relied on public grazing leases during the summer that were outside the study area. These distinctions were captured during our mapping sessions with participants.

Ideally, a year-by-year account of where livestock were pastured for the study time frame would have further refined this analysis. However, logistical considerations made this type of data collection effort impractical, since it would have taken excessive amounts of time on the part of livestock related land users. We felt that livestock related land users' knowledge of their operations and the general locations they told us they use for their spring, summer, and fall pasture locations were sufficient for our analysis.

Once the distance measurements were calculated for the features of interest, we ran MC simulations to determine how the observed distance distributions compared to distance distributions generated from random points. Monte Carlo simulations of random points were based upon the number of conflicts used for a particular test so that an accurate comparison could be made regarding the probability that the observed distribution would have occurred at random.

Beehive Data

We defined three analysis areas or buffers for MC simulations for all protected and unprotected beehives. A buffer is a zone of specified distance around a feature typically used for proximity analysis. We needed a delineated boundary around beehives in order to randomly place points for MC simulations since beehives were only located in the eastern half of the study area. Additionally, we wanted to define analysis areas that were biologically meaningful. We used different sizes of buffers (3.2 km, 4.8 km, 6.4 km) because it is probable that the extent of spatial attraction for each beehive corresponds to grizzly bear movements over several days, entailing several day ranges. Our hope was to develop MC tests at these different scales to determine the extent to which conflicts differed from a random distribution and thus establish if there was a

certain spatial scale at which bears were most likely responding to attractants like beehives in the study area. The original 1.6 km buffer area was too small for conducting MC simulations so we created buffers that were one, two, and three times larger than the original (Figure 6.2).

Beehives were grouped by protection status (protected/electrically fenced or unprotected/not fenced) and whether they had existed for more than four years to maximize beehive sample sizes for MC analysis. Conflicts were separated by the three buffers and by time intervals based upon the specific beehive group protection status used for each MC test. We calculated the average and median distances of all conflicts to the nearest beehive for all buffers and time intervals. We conducted MC simulations basing the number of random points on the number of conflicts that occurred in each of four time intervals that corresponded with beehive protection status. For each test we used 1000 iterations and calculated the number of averages and medians from random distributions that were greater than the observed mean and median, computed the MC p-value, and 95% confidence intervals.

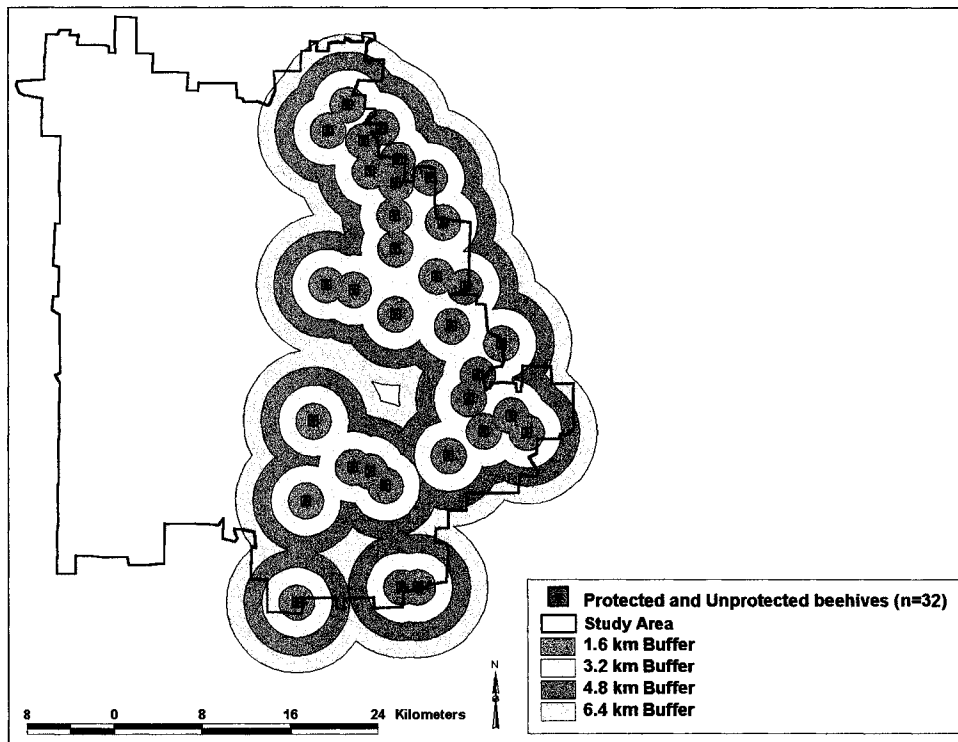


Figure 6.2. MC analysis areas with distribution of protected and unprotected beehive sites ($n = 32$).

Beehive Protection Status and Conflict Likelihood

We also used chi-square tests to compare beehive protection status with the likelihood of conflict using only beehive related conflicts ($n = 31$) during 1986-2001. We first identified beehives ($n = 12$) that had experienced conflicts and then buffered them by 3.2 km, 4.8 km, and 6.4 km (using the same rationale above) to include other beehives ($n = 15$) that were in close proximity but had not experienced conflicts. Those additional beehives were included in each buffer if they fell within or intersected a buffer perimeter. Our rationale for limiting the population of beehives for analysis was to compare protected beehives versus unprotected beehives in a portion of the study area that had experienced the most consistent bear activity based on prior beehive related conflict occurrence. If a beehive had been unprotected for any given period of time and then was

protected (electrically fenced) during 1986-2001, we included both of these types of status in our analysis. For example, if an unfenced beehive experienced a conflict prior to being fenced, we classified this as an unprotected beehive and ascribed a conflict to it. Once fenced, the beehive was classified as protected.

Riparian and Wetland Associated Vegetative Data

We determined the number of conflicts during 1986 and 2001 that were within delineated riparian and wetland associated vegetation and calculated the total areas of the riparian and wetland associated polygons in hectares. Riparian and wetland associated polygons were pooled to form the basis for buffer calculations. We also determined number of conflicts and calculated total areas for buffers created at 250 m intervals concentric to the riparian and wetland vegetation layer. We conducted a one-sample proportion z-test to assess differences in two proportions among each buffer and riparian and wetland associated polygons, where: Π_1 = proportion of the study area in a given buffer (**availability measure**) and Π_2 = proportion of study area conflicts within a given buffer (**use measure**). We assumed for this test that the proportion of each buffer to the study area size was a constant. We computed a z-test statistic for the actual riparian and wetland vegetation layer (0 m buffer) and for three different sized buffers that contained approximately one-half, three-fourths, and seven-eighths of all conflicts.

RESULTS

During 1986-2001, 57% of all conflicts were associated with either livestock or beehives and 80% of the 42 “residential, close proximity” conflicts occurred on ranches (Table 6.2). Slightly less than a third (30%) of all conflicts were associated with livestock depredations. Livestock management in the study area resulted in seasonal

concentrations of livestock in and adjacent to riparian areas. Riparian areas that serve as grizzly bear habitat, preferred forage by cattle, and for seasonal pasture use of sheep and cattle may create conditions for a contact zone where discrete conflict hotspots occur.

Table 6.2. Distribution of all conflicts ($n=178$) by type for 1986-2001.

<i>Conflict Type</i>	<i>Number of Conflicts</i>	<i>Percentage</i>
Grizzly bear injury	1	<1%
Livestock injury	1	<1%
Property damage	1	<1%
Residential/bird feeder	1	<1%
Human-grizzly bear encounter	2	1%
Reported as grizzly, beehive site damage, (unverified)	3	2%
Reported as grizzly, res. close prox. (unverified)	4	2%
Livestock stressed by grizzly bear presence	5	3%
Reported as grizzly, livestock depredation (unverified)	9	5%
Residential conflict, garbage/attractant related	12	7%
Grizzly bear feeding on livestock carcass (natural death)	13	7%
Beehive site damage	31	17%
Residential conflict, close proximity	42	24%
Livestock depredation	53	30%
Total	178	100%

Source: Data courtesy of MT Department of Fish, Wildlife & Parks.

Conflict Hotspots

We found that 73% of all spring conflicts ($n_1=93$) occurred in 6 spring conflict hotspots (A-F), 76% of all summer conflicts ($n_2=50$) occurred in 9 summer conflict hotspots (G-O), and 77% of all fall conflicts ($n_3=35$) occurred in 4 fall conflict hotspots (P-S) (Table 6.3). In combination, all 19 seasonal conflict hotspots accounted for 75% of all conflicts ($n=178$) during 1986-2001 (Table 6.3). It appears that the longer a conflict hotspot exists, the more conflicts one can expect in that location and suggests that hotspots are a locus for chronic problems over time (see Table 6.3). We present findings for each seasonal conflict hotspot followed by two maps that illustrate locations of seasonal hotspots and seasonal hotspots with landscape features and unique attractants that were available during that particular season. The visual display of landscape features

and attractants serves to illustrate the spatial and temporal links between human agricultural activities and the occurrence of human-grizzly bear conflicts. We also present three tables that contain information on the number of conflicts per year for each seasonal hotspot (Table 6.3), a table with the number and types of conflicts that occurred in each seasonal hotspot (Table 6.4), and a table that identifies chronic hotspots for each season (Table 6.5). This sequence establishes that conflict hotspots are spatially discrete, that conflict types differ seasonally depending on the specific attractants that are available, and that certain hotspots are chronic.

Spring Conflict Hotspots

Spring conflict hotspots were clustered along riparian corridors and tended to be found in the lower elevations of the central and eastern portions of the study area (Figure 6.3). Hotspots A and B were the closest (≈ 8.23 km) to the national forest boundary within the study area. Hotspots C and E are both located within a river bottom and had the highest conflict densities. All hotspots had three or more years with conflicts and both hotspots C and E had eight years with conflicts and together accounted for 67% of the conflicts ($n=68$) found in all spring conflict hotspots (Table 6.3). The bulk of conflicts found in hotspots for this season were either residential, close proximity (35%), livestock depredations (25%), beehive related (15%), or associated with residential attractants (5%) (Table 6.4). All hotspots except hotspot F had both residential, close proximity conflicts and livestock depredations.

With the exception of hotspot D, hotspots A, B, C, E, and F all had riparian and wetland associated vegetation within the hotspot and five hotspots (A,B, C, D, E) out of six were either bisected by or adjacent to a river or creek. Five (A, B, D, E, F) out of six hotspots had bone yards and four (C, D, E, F) had unfenced and fenced beehives either within or in close proximity to the hotspot. All hotspots had calving areas and spring cattle pastures either within or directly adjacent to the continuous density surface that made up the hotspot (Figure 6.4). Additionally, hotspots A, D, and E had sheep lambing areas and hotspots A – D all had spring sheep pastures (A and E were historic use). The resolution of Figure 6.4 makes it difficult to see both sheep lambing areas and spring sheep pastures.

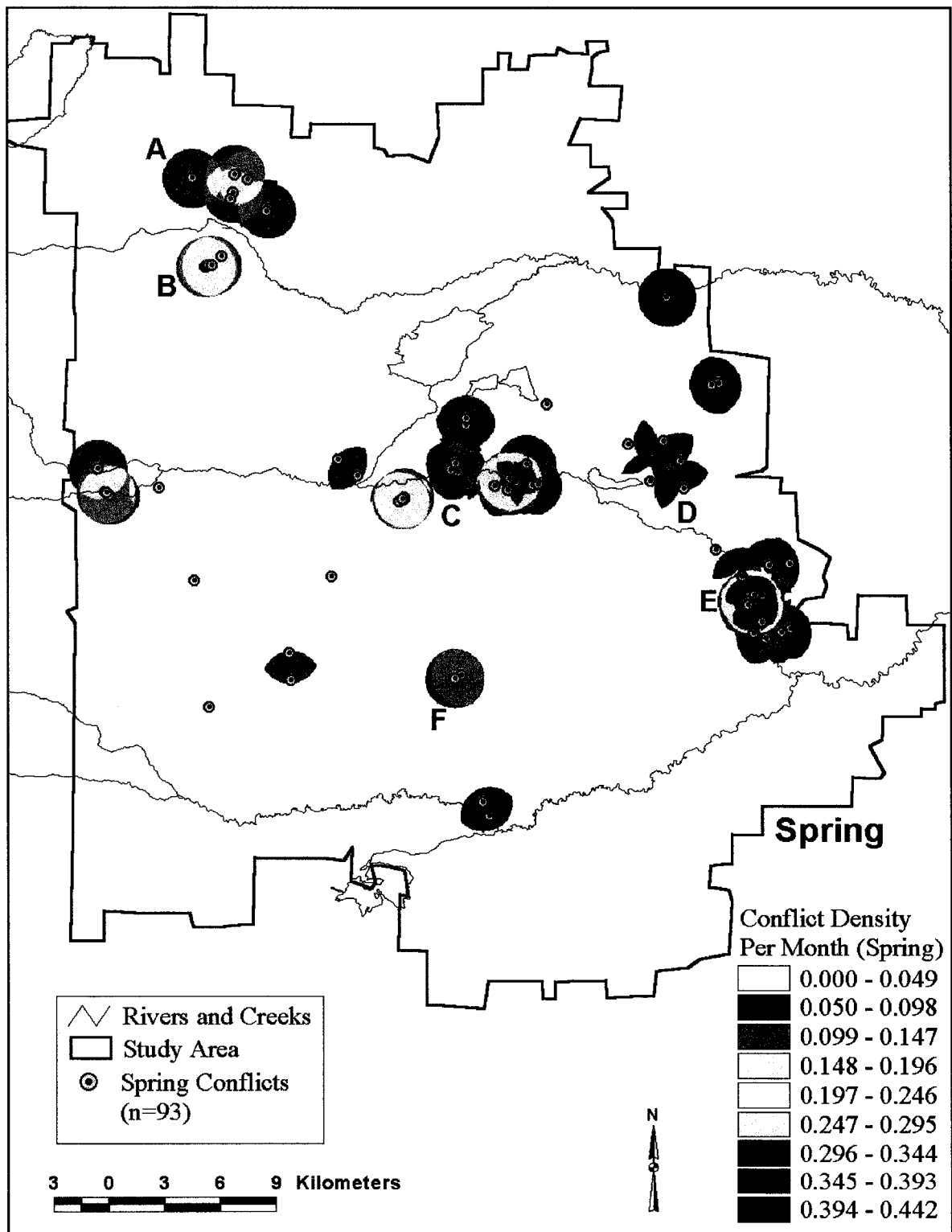


Figure 6.3. Spring isopleth conflict densities for hotspots A-F ($n/\text{km}^2/\text{month}$; $n=93$)
 The interval 0.099 – 0.147 corresponds with ≥ 3 conflicts/ km^2/mo . Density surfaces not enumerated by a letter did not meet operational hotspot definitions. Hotspot F ($n=4$) had conflicts with identical UTM coordinates.

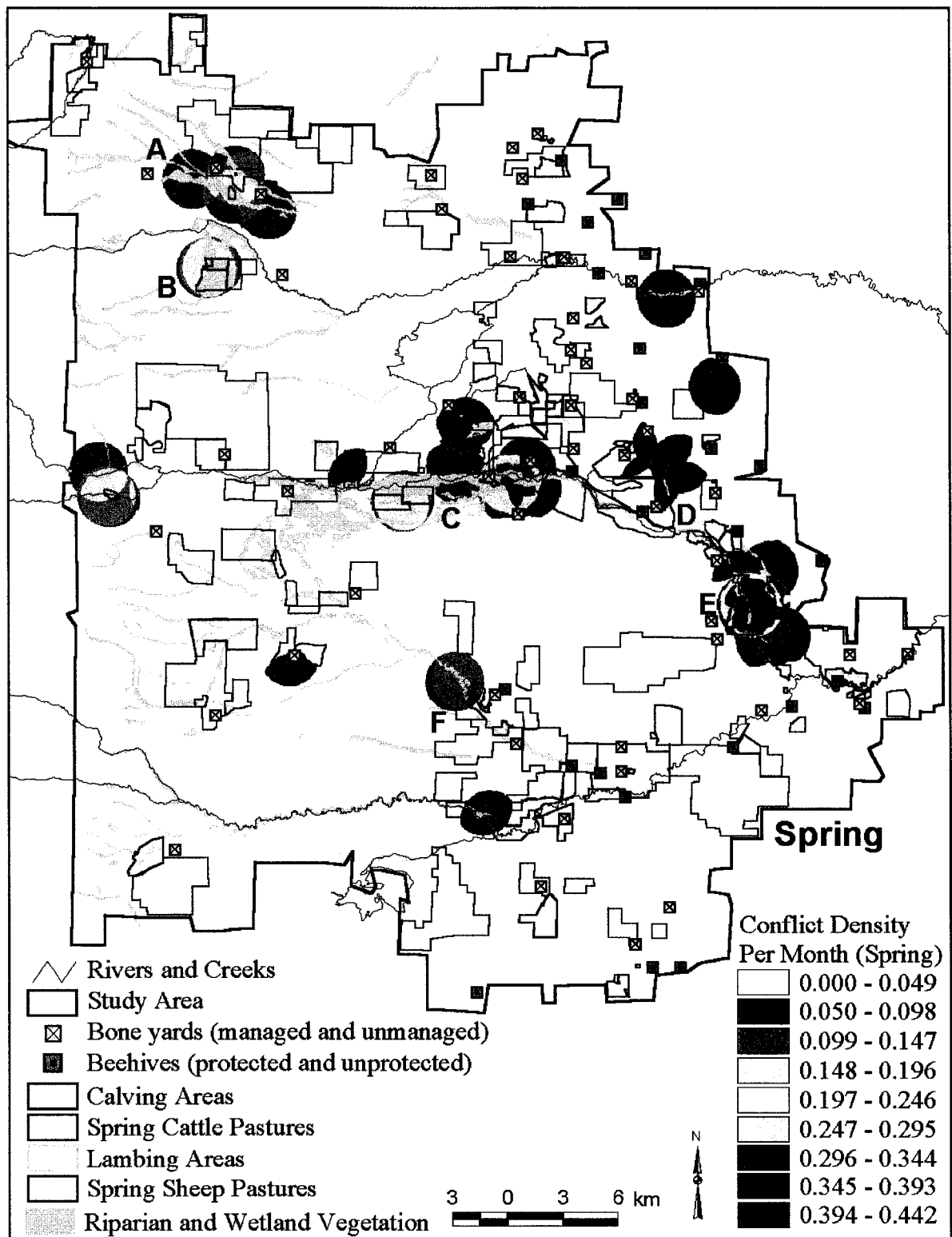


Figure 6.4. Spring isopleth conflict densities for hotspots A-F ($n/\text{km}^2/\text{month}$; $n=93$) with landscape features and seasonally available attractants.

Summer Conflict Hotspots

Summer hotspots were more dispersed throughout the study area and were less clustered along river and creek bottoms with the exception of hotspots K, M, N, and O (Figure 6.5). Hotspots K and L had the greatest densities of conflicts per month but no one hotspot or group of hotspots dominated the summer season in terms of sheer numbers of conflicts (Table 6.3). Despite that the summer season had the greatest conflict densities (25 conflict/mo.), summer hotspots had fewer numbers of years with conflicts compared with spring or fall. Hotspots K and L had the most, with five and four years of conflicts respectively and several hotspots only had conflicts for two years during 1986-2001. Of all summer conflicts (n=38) found in the 9 hotspots, more than half were associated with livestock depredations (21%) or beehive site damage (31%). Hotspots G, H, I, J, and K all had livestock depredations and hotspots I, J, K, N, and O had conflicts that involved beehive site damage (Table 6.4).

Hotspots G, H, K, L, M, and N had riparian and wetland associated vegetation found within the hotspot and were either adjacent (G) to or bisected by a creek or river. Seven (G, H, I, J, K, L, O) out of nine hotspots had bone yards within close proximity (G and J) or within the hotspot. Hotspots I, J, K, L, N, O all had beehives within their density surface areas. Several beehives near and within hotspots I, J, and K had been unfenced during 1986-2001. Given the extensive distribution of summer cattle grazing in the study area, it was not surprising that hotspots G, H, K, L, M, and O were bisected by these pastures. Additionally, there were livestock depredations involving historic and current sheep production in hotspots K and I (Figure 6.6).

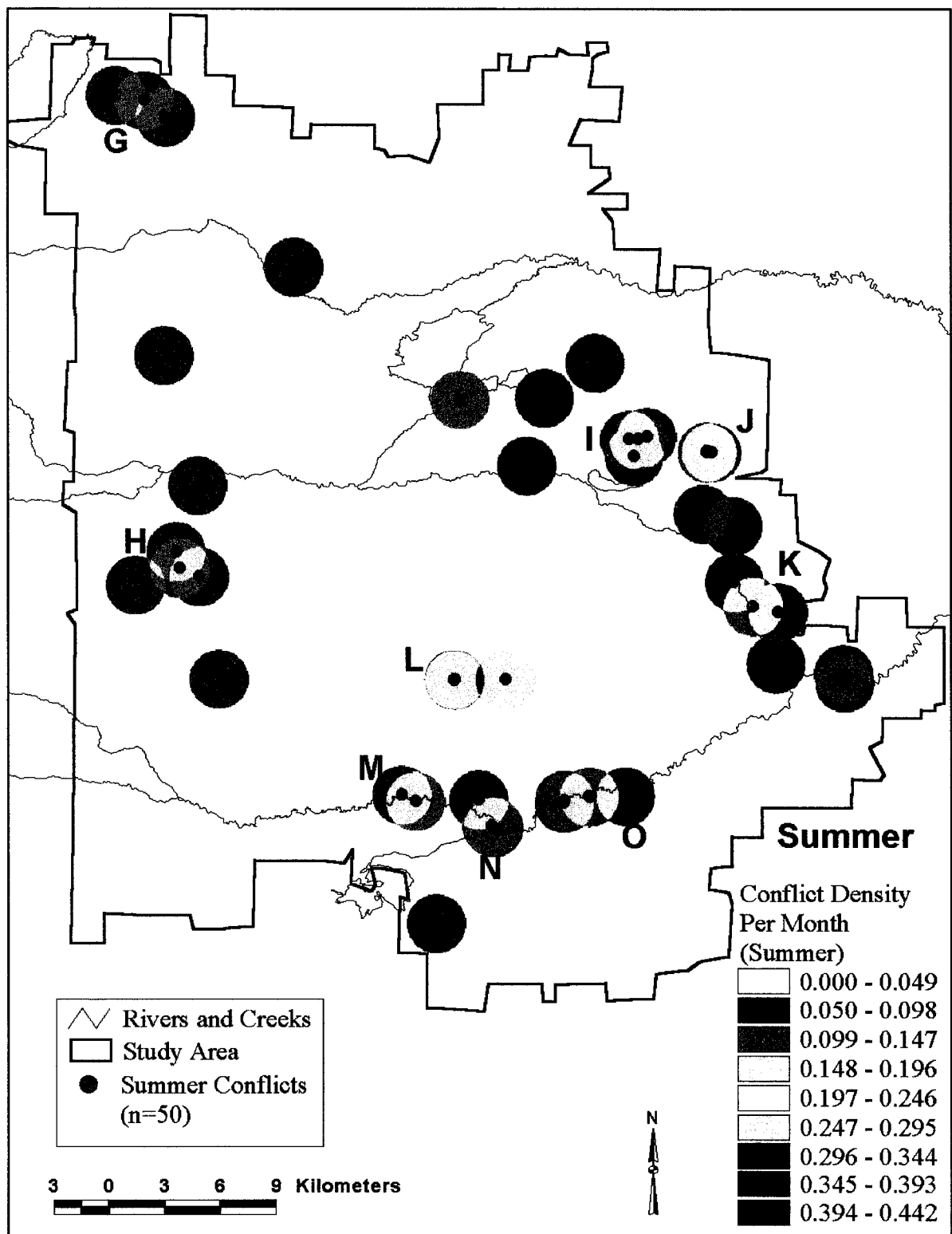


Figure 6.5. Summer isopleth conflict densities for hotspots G-O ($n/\text{km}^2/\text{month}$; $n=50$). The interval 0.148 – 0.0196 corresponds with ≥ 3 conflicts/ km^2/mo . Density surfaces not enumerated by a letter did not meet operational hotspot definitions. Hotspots J ($n=3$) and L ($n=6$) had conflicts with identical UTM coordinates.

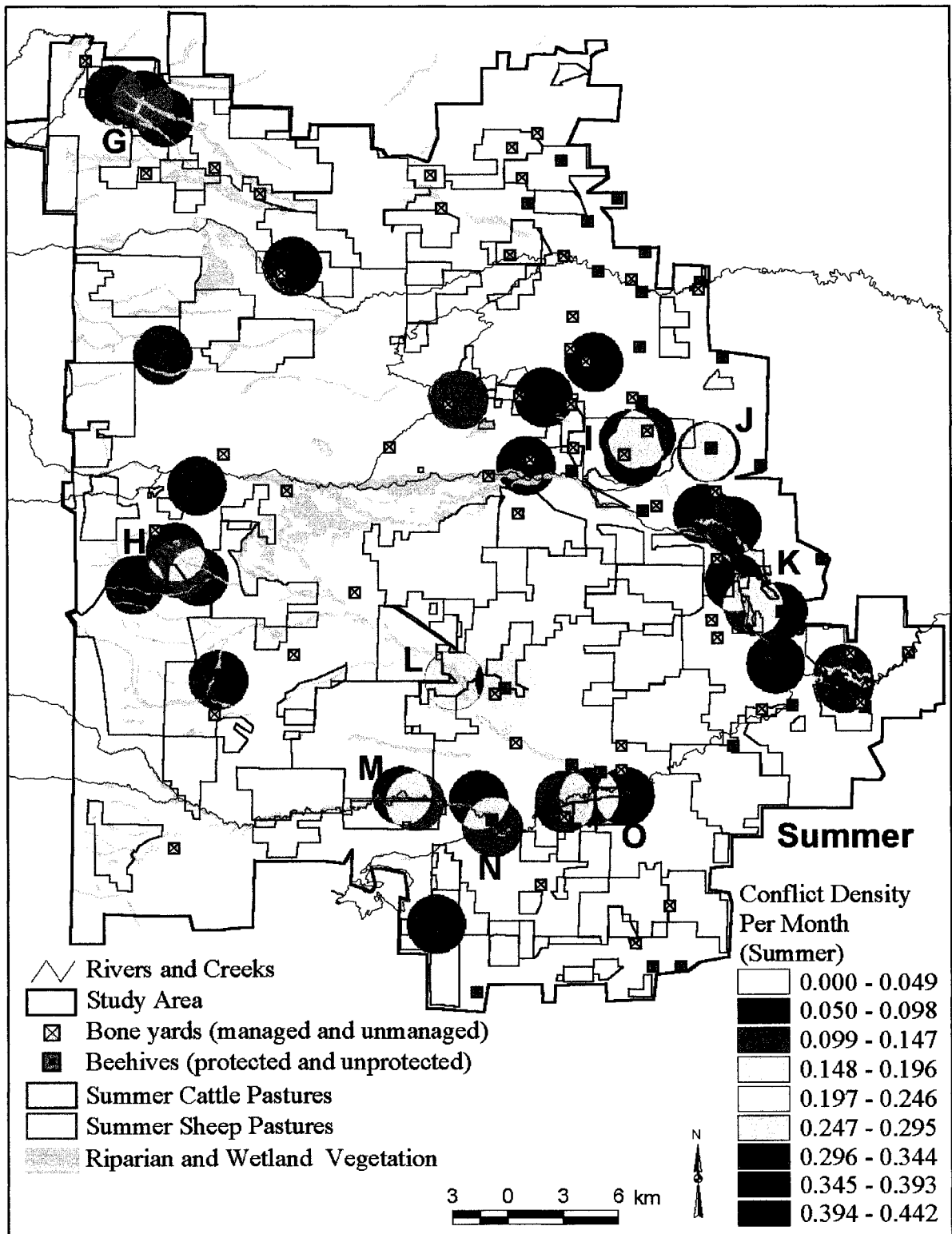


Figure 6.6. Summer isopleth conflict densities for hotspots G-O ($n/\text{km}^2/\text{month}$; $n=50$) with landscape features and attractants.

Fall Conflict Hotspots

Fall hotspots tended to be in close proximity to riparian corridors in the study area. There was distinct clustering of conflicts in hotspots Q, R, and S along river and creek bottoms (Figure 6.7). There were only four hotspots based on our definitions for the fall season and more than half (57%) of all fall conflicts were found in hotspots Q and R. Hotspot R had the greatest overall conflict density per month. Hotspot S had the fewest number of years with conflict (2) and P, Q, and R all had more than four years with one or more conflicts (Table 6.3). The majority (70%) of conflicts found in hotspots were beehive site damage (15%), residential, close proximity (22%), and livestock depredations (33%). Hotspot R had all three of the above conflict types (Table 6.4).

All four hotspots had riparian and wetland associated vegetation and hotspots Q, R, and S were bisected by a river or creek. All four hotspots had bone yards and three (Q, R, and S) out of four had beehives. Fall cattle pastures were present in all four hotspots and three (P, Q, R) had historic fall sheep pastures within the hotspots (Figure 6.8). The fall sheep pasture in Hotspot Q was also used by cattle and thus was obscured in Figure 6.8.

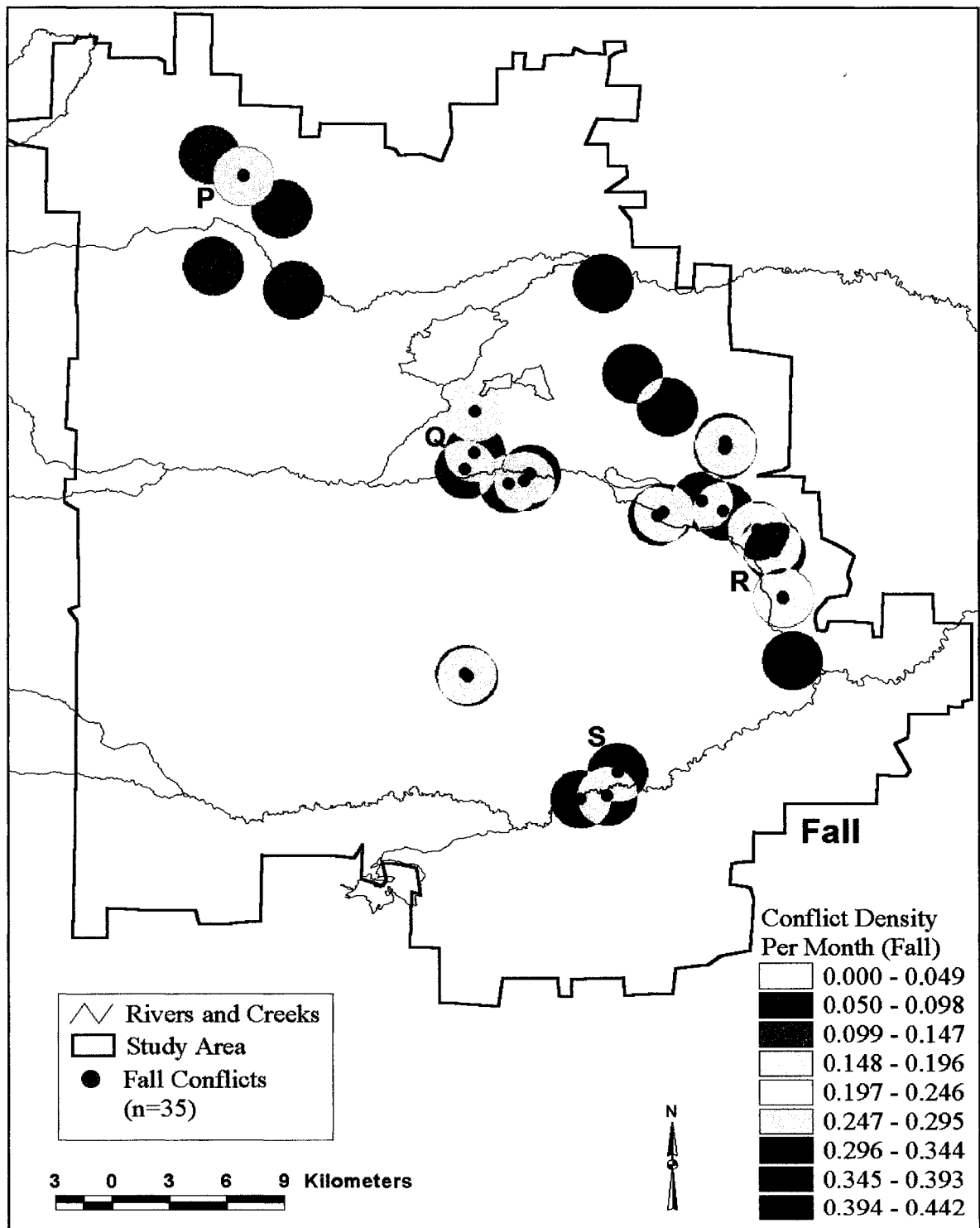


Figure 6.7. Fall isopleth conflict densities for hotspots P-S ($n/\text{km}^2/\text{month}$; $n=35$). The interval 0.247 – 0.295 corresponds with ≥ 3 conflicts/ km^2/mo . Density surfaces not enumerated by a letter did not meet operational hotspot definitions.

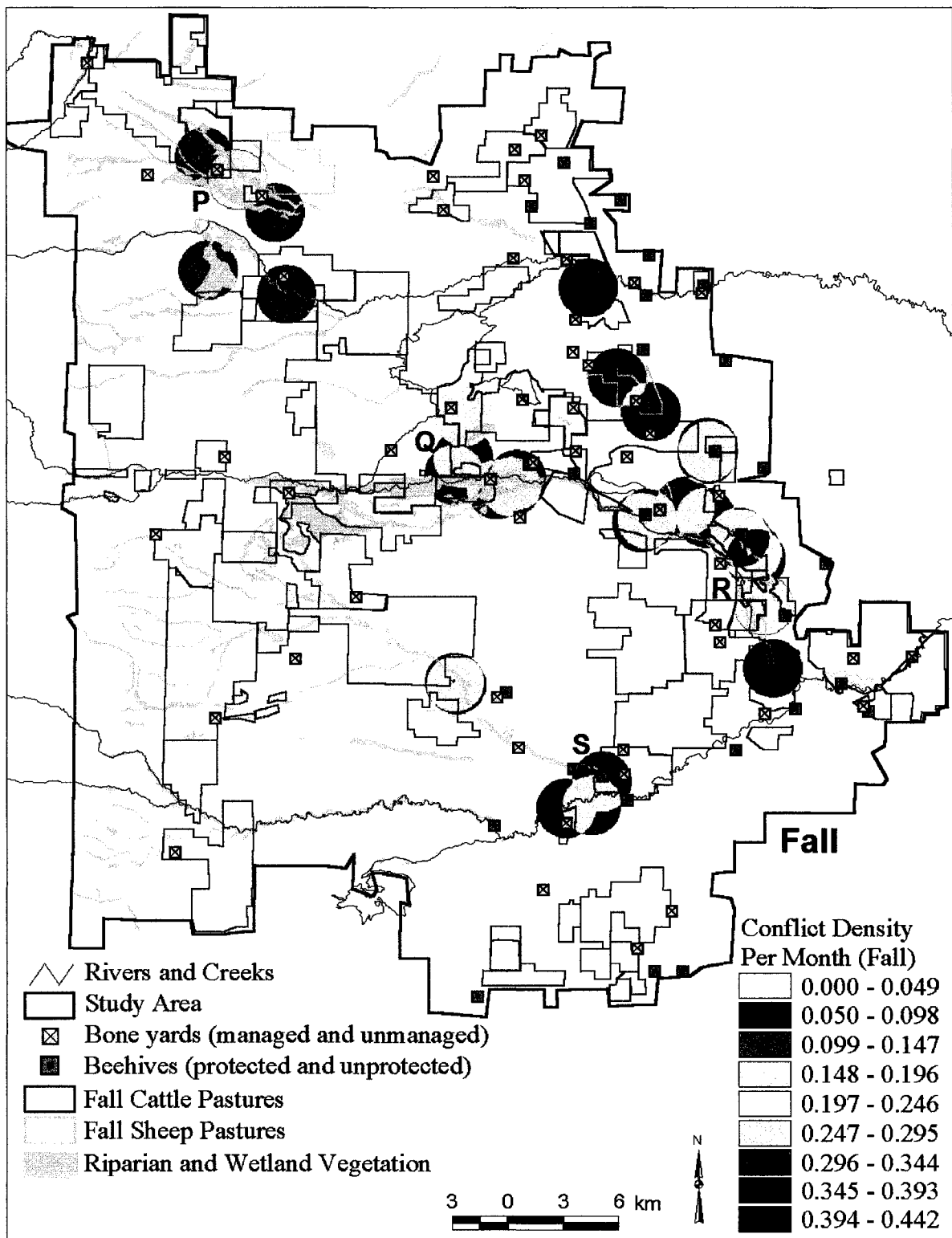


Figure 6.8. Fall isopleth conflict densities for hotspots P-S ($n/\text{km}^2/\text{month}$; $n=35$) with landscape features and attractants.

Table 6.3. Number of conflicts per year for seasonal conflict hotspots (A-S) based on conflict densities per month and total number of years with conflict(s) by hotspot for the study area on the Rocky Mountain Front, MT.

	Number of Conflicts in Spring Hotspots												Number of Conflicts in Summer Hotspots												Number of Conflicts in Fall Hotspots					Totals
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S											
Year	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S											
1986	1		2								1																			
1987																		1												
1988																	1													
1989																	2	1												
1990			1	1	2						1		2																	
1991	3	3	2		2				1			3		1		1		3	2											
1992			1			1									2				1											
1993												1		1	1	1														
1994		1						1							1	1	2													
1995	3		10		2			2	1																					
1996			5	1	1	1			3		2		1	1			2	2												
1997	1		2		6		1	1			1																			
1998	2	2					2			2	2					1		5												
1999		1	1		1							1			1															
2000					5	2												1												
2001				1	1							1																		
Totals	10	7	24	3	20	4	3	4	4	3	7	6	3	3	5	4	7	13	3											
Years of Conflict	5	4	8	3	8	3	2	3	2	2	5	4	2	3	4	4	4	6	2											

Note: We conducted a Spearman's rank order correlation test to determine if there was a relationship between the total number of conflicts that occurred in a given hotspot and the number of years that hotspot had conflicts. We found that for hotspots across all seasons (n=19) that numbers of conflicts were correlated with years of conflicts ($r^2 = .918$, $p\text{-value} = .005$) suggesting that conflicts appear to occur chronically over time in hotspots.

Table 6.4. Number of conflicts by type for seasonal conflict hotspots (A-S) based on conflict densities per month for study area on the Rocky Mountain Front, MT.

Conflict Types	No. of Conflicts in Spring Hotspots												No. of Conflicts in Summer Hotspots												No. of Conflicts in Fall Hotspots					Totals					
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S																
Grizzly bear injury																	1																		1
Livestock injury			1																															1	
Property damage												1																						1	
Residential/ Bird Feeder	1																																	1	
Human-grizzly encounter																		1																1	
Rep. as grizzly, beehive damage, (unverified)					1																													3	
Rep. as grizzly, res. close proximity, (unverified)					1	2						1																						4	
Livestock stressed by bear		2				1									1																			4	
Rep. as grizzly , livestock depredation, (unverified)			2					1					2		1		1																	7	
Residential conflict, garbage/attractant related	1	1	2									2																				1		7	
Grizzly bear feeding on livestock carcass (nat.	1			1			2	1	1				1		1	1	1																10		
Beehive site damage			2		8					2	4	3		2	1																			26	
Residential conflict, close proximity	4	1	12	1	5	1					1				1	1	1	2	2														32		
Livestock depredation	3	3	5	1	5		1	2	3	1	1				1	2	3	4															35		
Total	10	7	24	3	20	4	3	4	4	3	7	6	3	3	5	4	7	13	3															133	

Chronic Conflict Hotspots

Using our definition for identifying chronic hotspots as those with at least four years of conflict, we found that there were 10 chronic hotspots that accounted for 58% of all conflicts during 1986-2001 (Table 6.5) (Figure 6.9). More than a third (34%) of all conflicts occurred in spring chronic hotspots with summer and fall chronic hotspots accounting for 10% and 14% of all conflicts respectively (Table 6.5).

Table 6.5. Chronic conflict¹ hotspots for spring, summer, and fall seasons based on hotspots that had 4 or more years of conflicts (in total) for the study area on the Rocky Mountain Front, MT.

	<i>Number of Conflicts in Chronic Spring Hotspots</i>				<i>Number of Conflicts in Chronic Summer Hotspots</i>			<i>Number of Conflicts in Chronic Fall Hotspots</i>			
Year	A	B	C	E	K	L	O	P	Q	R	Totals
1986	1		2		1						4
1987										1	1
1988									1		1
1989									2	1	3
1990			1	2	1						4
1991	3	3	2	2		3		1		3	17
1992			1				2				3
1993						1	1	1			3
1994		1					1	1	2		5
1995	3		10	2							15
1996			5	1	2				2	2	12
1997	1		2	6	1						10
1998	2	2			2			1		5	12
1999		1	1	1		1	1				5
2000				5						1	6
2001				1		1					2
Totals	10	7	24	20	7	6	5	4	7	13	103
Years of Conflict	5	4	8	8	5	4	4	4	4	6	

¹ Non-chronic hotspots are found in Table 6.3 and are: Spring (D,F); Summer (G,H,I,J,M,N); Fall (S).

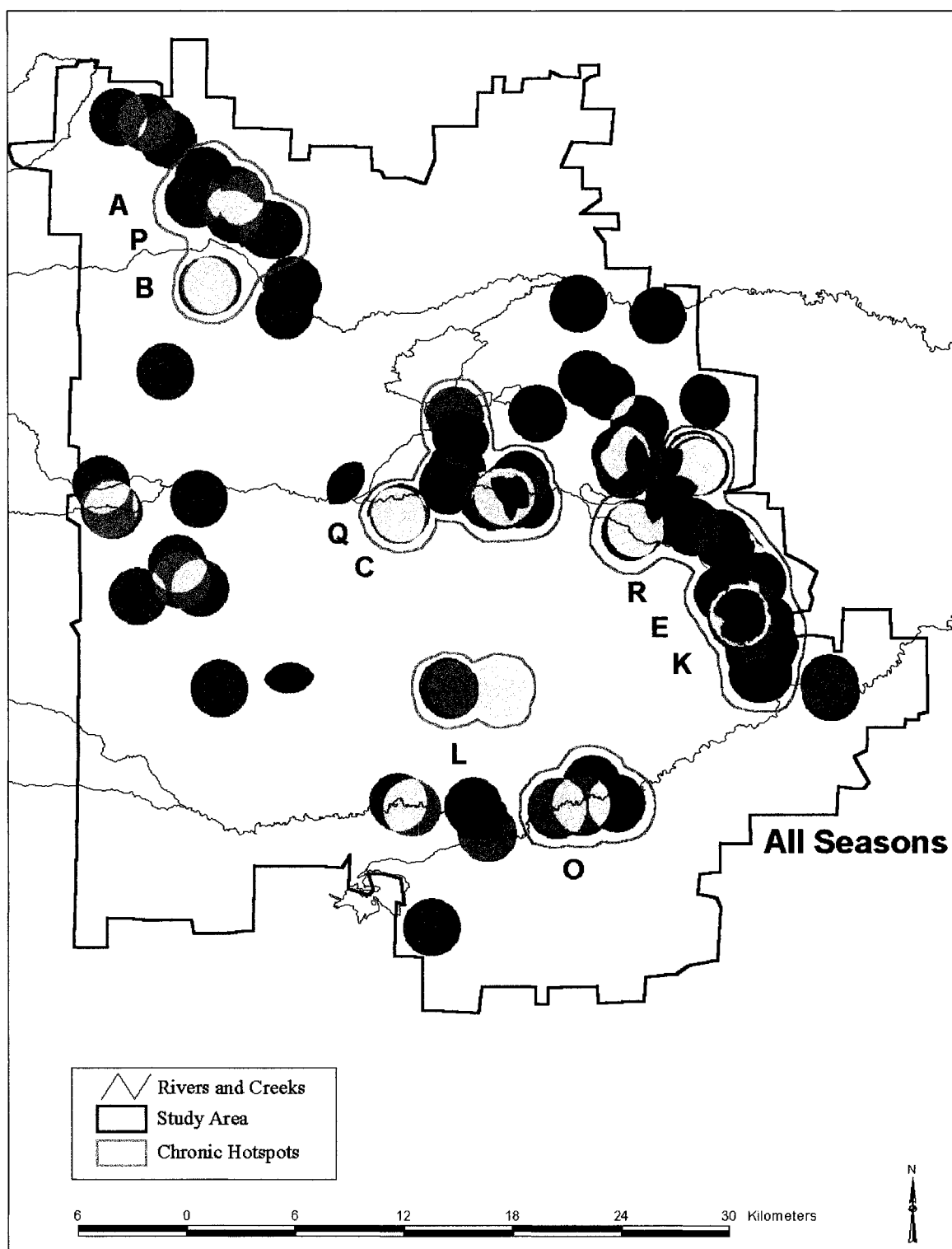


Figure 6.9. Chronic hotspots (circled in green) for all seasons based on normalized seasonal density maps. Density surfaces not enumerated by a letter did not meet operational definition of a chronic hotspot.

Numbers of Grizzly Bears Associated with Conflict Hotspots

Twenty-two individual grizzly bears were associated with the seasonal conflict hotspots that we identified (Table 6.6). Four individuals found at multiple hotspots (grizzly bears #173, #187, #338, and #500). Individual grizzly bears that were associated with conflict hotspots were identified by MFWP and recorded in the conflict database through radio collaring, lip tattoos, and or ear tags. In many cases, individuals found at conflict hotspots were likely involved in other conflicts and thus had been previously identified. Most conflicts were associated with unknown bear identities.

Table 6.6. Numbers of unique individual grizzly bears, total number of conflicts with known bear identities, and total number of conflicts with unknown bear identities found in seasonal hotspots A-S ($n=19$) based on conflict densities per month.

<i>Hotspots</i>	<i>Number of Known Unique Individuals</i>	<i>Total Number of Conflicts with Known Bear Identities</i>	<i>Total Number of Conflicts with Unknown Identities</i>
Spring (A - F)	14	24	44
Summer (G - O)	5	9	29
Fall (P - S)	3	8	19
Total	22	41	92

Common Features and Attractants in Hotspots and Seasonal Overlap for 1986-2001

Certain landscape features and attractants were found in common across all seasonal hotspots. A majority of hotspots within each season all shared the following: 1) the presence of riparian and wetland associated vegetation, 2) spatial proximity to a river or creek, 3) the presence of bone yards, and 4) the presence of beehives (Table 6.7).

Table 6.7. Landscape features and attractants found in spring ($n=6$), summer ($n=9$), and fall ($n=4$) conflict hotspots. Figures denote the number of hotspots within each season that are associated with a specific landscape feature or attractant.

<i>Type of Landscape Feature and Attractant Associated with Seasonal Hotspots</i>	<i>Seasonal Hotspots</i>		
	<i>Spring ($n=6$)</i>	<i>Summer ($n=9$)</i>	<i>Fall ($n=4$)</i>
Riparian and wetland associated vegetation	5	6	4
Adjacent / bisected by river or creek	5	5	3
Bone yards	4	7	4
Beehives	4	6	3
Calving areas	6	--	--
Sheep lambing areas	3	--	--
Spring sheep pastures	5	--	--
Summer cattle pastures	--	6	--
Summer sheep pastures	--	4	--
Fall cattle pastures	--	--	4
Fall sheep pastures	--	--	3

Since we observed seasonal overlap in many of the hotspots, we have constructed a conflict density map based on all conflicts ($n=178$) during 1986-2001. The map is non-normalized and there are no definitions used to identify individual hotspots. The northwest, central, east, and southern portions of the study area contain the areas of highest densities (Figure 6.10). This figure provides a useful means to observe the general patterns of conflicts that have occurred over 16 years. While not as detailed as the normalized seasonal conflict hotspot maps, this figure also helps establish that the scale of annual conflict locations are relatively tightly clustered in the study area.

A more precise way of accounting for overlap is to actually compare seasonal conflict hotspots from one season to the next. We were interested in documenting those

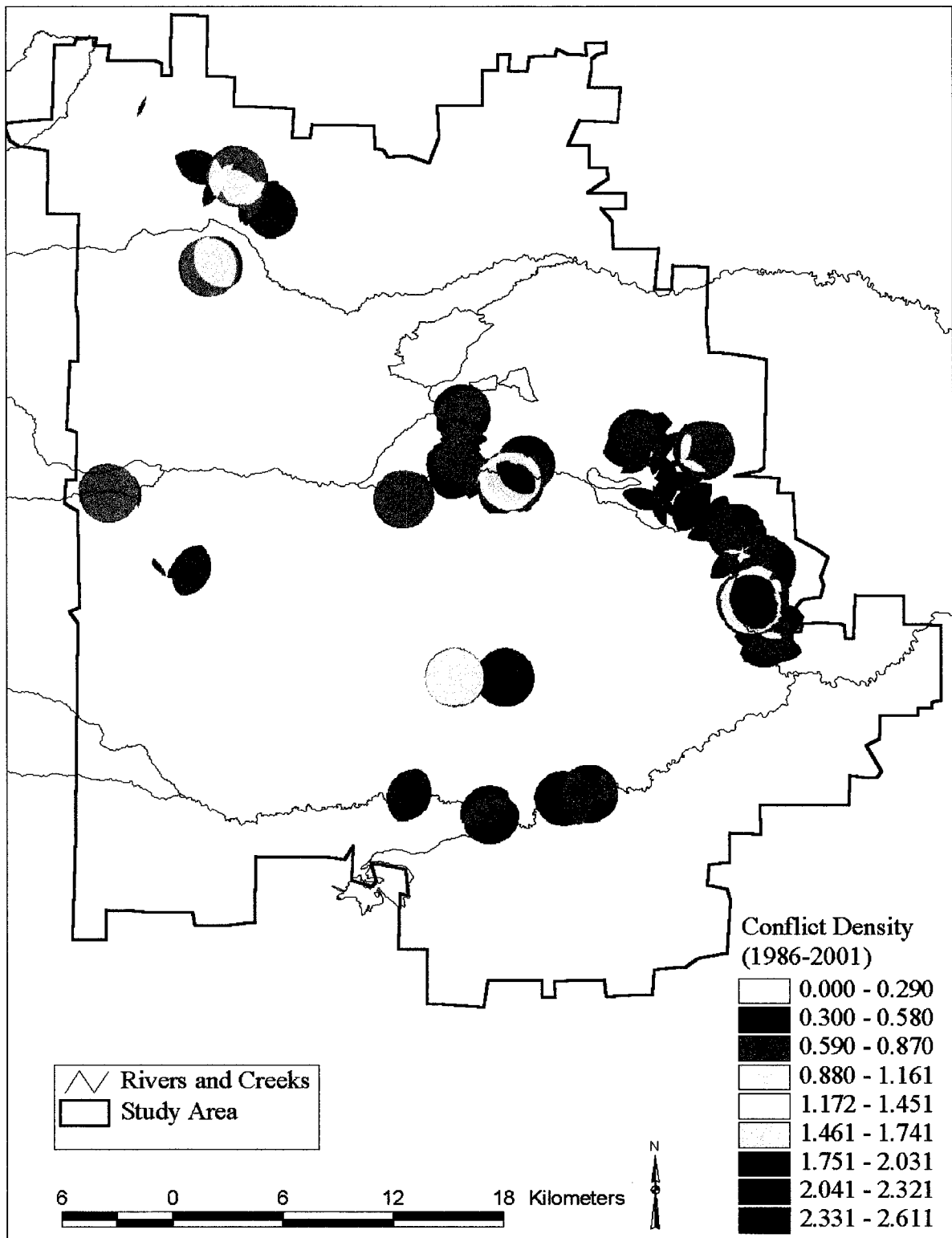


Figure 6.10. Isopleth conflict density for 1986-2001 (n/km^2 ; $n=178$).

specific hotspots that had distinct spatial overlap based on our normalized density maps (Table 6.8). We also found that overlapping hotspots had year-round attractants like bone yards and beehives that were located in close proximity to one another. Sixty two percent of all conflicts were found in the overlapping conflict hotspots and all had bone yards and beehives located in the hotspots. The spatial overlap and resulting clustering of conflicts over seasonal and annual scales may be a result of year-round attractant availability coupled with pulses of season-specific attractants that are associated with conflicts.

Table 6.8. Seasonal hotspots that spatially overlapped and number of conflicts found within hotspots and year-round attractants found in overlapping hotspots.

<i>Season to Season Overlap of Hotspots</i>	<i>Total Number of Conflicts¹</i>	<i>Year-Round Attractants Found in Overlapping Hotspots</i>
<i>Spring to Summer Overlap</i>		
Spring-D + Summer-I, J	12	Bone yards, beehives
Spring-E + Summer-K	27	Bone yards, beehives
Spring-F + Summer-L	6	Bone yards, beehives
<i>Summer to Fall Overlap</i>		
Summer-G + Fall-P	7	Bone yards
Summer-K + Fall-R	13	Bone yards, beehives
Summer-O + Fall-S	8	Bone yards, beehives
<i>Fall to Spring Overlap</i>		
Fall-P + Spring -A	14	Bone yards
Fall-Q + Spring-C	31	Bone yards, beehives
Fall-R + Spring-D, E	13	Bone yards, beehives
Total	131	

¹ Conflict counts were not duplicated for hotspots that crossed seasons.

Rivers and Creeks and Conflict Locations

Conflicts that occurred during 1986-2001 clustered tightly along rivers and creeks throughout the study area. The average distance of all conflicts to the nearest river or creek was 1.8 km (Table 6.9). A distance this small was very unlikely to have occurred by chance (MC p-value <.0005).

Table 6.9. Average and median distances of all conflicts ($n=178$) to nearest rivers and creeks with MC simulation averages, medians, p-values, and 95% C.I. using 1000 iterations.

<i>Feature of interest</i>	<i>Conflicts</i>	<i>MC Simulations</i>	<i>p</i>	<i>95% C.I.</i>
Average distance to nearest river or creek	1.8 km	2.9 km	<.0005	(2.6,3.2) km
Median distance to nearest river or creek	0.9 km	2.5 km	<.0005	(2.0,3.0) km

Livestock Pastures, Bone Yards, and Conflict Locations

Conflicts were strongly associated with livestock grazing pastures or lambing or calving areas during the spring and fall (MC p-values <.0005) (Table 6.10). Spring and fall conflicts were strongly associated with sheep lambing areas and sheep fall pastures, respectively (MC p-values <.0005). Conflicts were also strongly associated with calving areas and spring pastures for cattle and with fall cattle pastures (MC p-values <.0005).

Table 6.10. Average and median distances of spring ($n=93$), summer ($n=50$), and fall ($n=35$) conflicts to centroids of lambing areas ($n=16$), spring sheep pastures ($n=13$), summer sheep pastures ($n=17$), and fall sheep pastures ($n=10$) and centroids of cattle calving areas ($n=89$), spring cattle pastures ($n=86$), summer cattle pastures ($n=121$), and fall cattle pastures ($n=93$) with MC simulation averages, medians, p-values, and 95% C.I. using 1000 iterations.

<i>Feature of Interest</i>		<i>Conflicts</i>	<i>MC Simulations</i>	<i>p</i>	<i>95% C.I.</i>
Sheep Grazing Data:					
Spring Conflicts	Ave. dist. to nearest spring lambing area	5.2 km	10.7 km	<.0005	(9.3,12.3) km
	Med. dist. to nearest spring lambing area.	3.8 km	8.7 km	<.0005	(7.0,11.1) km
	Ave. dist. to nearest spring pasture	5.2 km	3.5 km	1.000	(3.1,4.0) km
	Med. dist. to nearest spring pasture	3.5 km	3.2 km	0.858	(2.7,3.8) km
Summer Conflicts	Ave. dist. to nearest summer pasture	5.6 km	8.4 km	<.0005	(6.8,10.1) km
	Med. dist. to nearest summer pasture	5.1 km	6.6 km	0.028	(5.1,8.5) km
Fall Conflicts	Ave. dist. to nearest fall pasture	1.0 km	2.8 km	<.0005	(2.2,3.4) km
	Med. dist. to nearest fall pasture	0.9 km	2.4 km	<.0005	(1.8,3.1) km
Cattle Grazing Data:					
Spring Conflicts	Ave. dist. to nearest spring calving area	1.7 km	3.5 km	<.0005	(3.1,3.9) km
	Med. dist. to nearest spring calving area	0.7 km	3.2 km	<.0005	(2.6,3.8) km
	Ave. dist. to nearest spring pasture	1.4 km	2.8 km	<.0005	(2.5,3.2) km
	Med. dist. to nearest spring pasture	1.3 km	2.4 km	<.0005	(2.0,3.0) km
Summer Conflicts	Ave. dist. to nearest summer pasture	2.2 km	2.3 km	0.194	(2.0,2.7) km
	Med. dist. to nearest summer pasture	1.7 km	2.2 km	<.0005	(1.7,2.6) km
Fall Conflicts	Ave. dist. to nearest fall cattle pasture	1.0 km	2.8 km	<.0005	(2.2,3.4) km
	Med. dist. to nearest fall cattle pasture	0.9 km	2.4 km	<.0005	(1.8,3.2) km

Additionally, we compared the distance of spring conflicts ($n=93$) to the nearest calving or lambing areas, considered jointly ($n=105$). We also compared all conflicts ($n=178$) to the nearest bone yard (carcass dump) locations ($n=53$). Spring conflicts and all conflicts were strongly spatially associated with calving or lambing areas (MC p-values < .0005) and bone yards, respectively (MC p-values <.0005) (Table 6.11).

Table 6.11. Average and median distances of spring conflicts ($n=93$) to combined calving and lambing areas ($n=105$) for sheep and cattle and average and median distances of all conflicts ($n=178$) to bone yards ($n=53$) with MC simulation averages, medians, p-values, and 95% C.I. using 1000 iterations.

<i>Feature of interest</i>		<i>Conflict s</i>	<i>MC Simulation</i>	<i>p</i>	<i>95% C.I.</i>
Cattle and Sheep Grazing Data:					
Spring Conflicts	Ave. distance to nearest calving or lambing area	1.4 km	3.5 km	<.0005	(3.1,4.0) km
	Med. distance to nearest calving or lambing area	0.7 km	3.2 km	<.0005	(2.7,3.8) km
Cattle and Sheep Bone yards¹:					
All Conflicts	Ave. distance to nearest bone yard	2.1 km	3.1 km	<.0005	(2.9,3.4) km
	Med. distance to nearest bone yard	1.9 km	2.9 km	<.0005	(2.5,3.2) km

¹ In the MC analysis above, we used all bone yards ($n=53$) and all conflicts ($n=178$). Montana Department of Fish, Wildlife and Parks has a carcass redistribution program where carrion from ranches that are placed on bone yards are collected in the spring and randomly redistributed to remote locations along the RMF where they likely serve as important sources of protein for grizzly bears after den emergence (Madel, 1996). Livestock producers started participating in the program at various times during 1986-2001, making it impractical to run MC simulations for each time interval with a different sample size. Since grizzly bears may also continue to investigate managed bone yards if they have found carrion in the past and since there were 12-15 bone yards out of a total of approximately 53 bone yards that are part of the MFWP program, we felt justified using all bone yards in the MC simulations.

The strong associations of conflicts with bone yards is not surprising given that the bone yards tend to be located near calving or lambing areas (Figure 6.11). Moreover, bone yards are used extensively to deposit calves that died during the spring calving season.

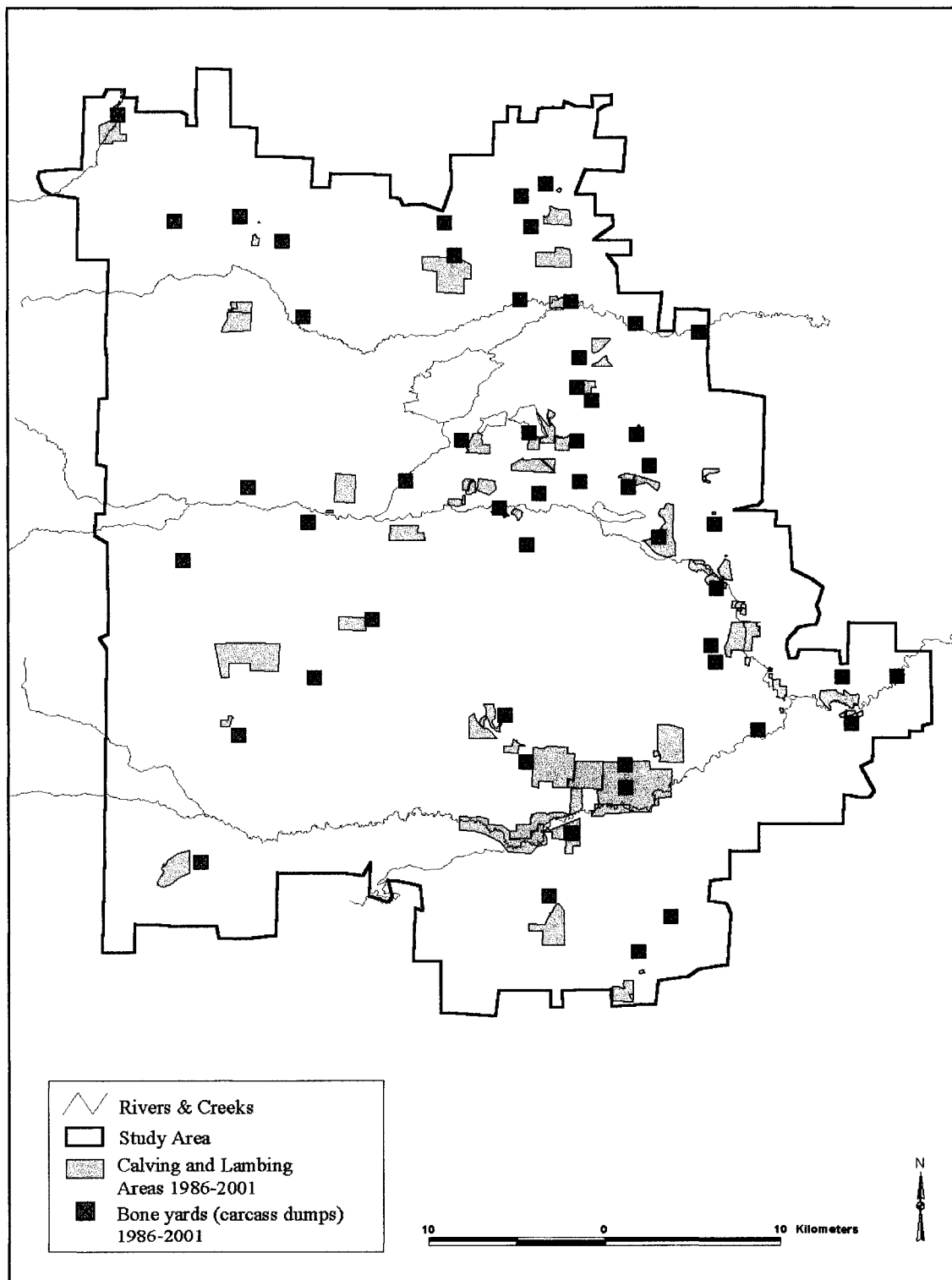


Figure 6.11. Bone yard locations ($n = 53$) and calving and lambing areas ($n = 105$) during 1986-2001 and rivers and creeks in the study area.

Beehives, Protection Status, and Conflict Locations

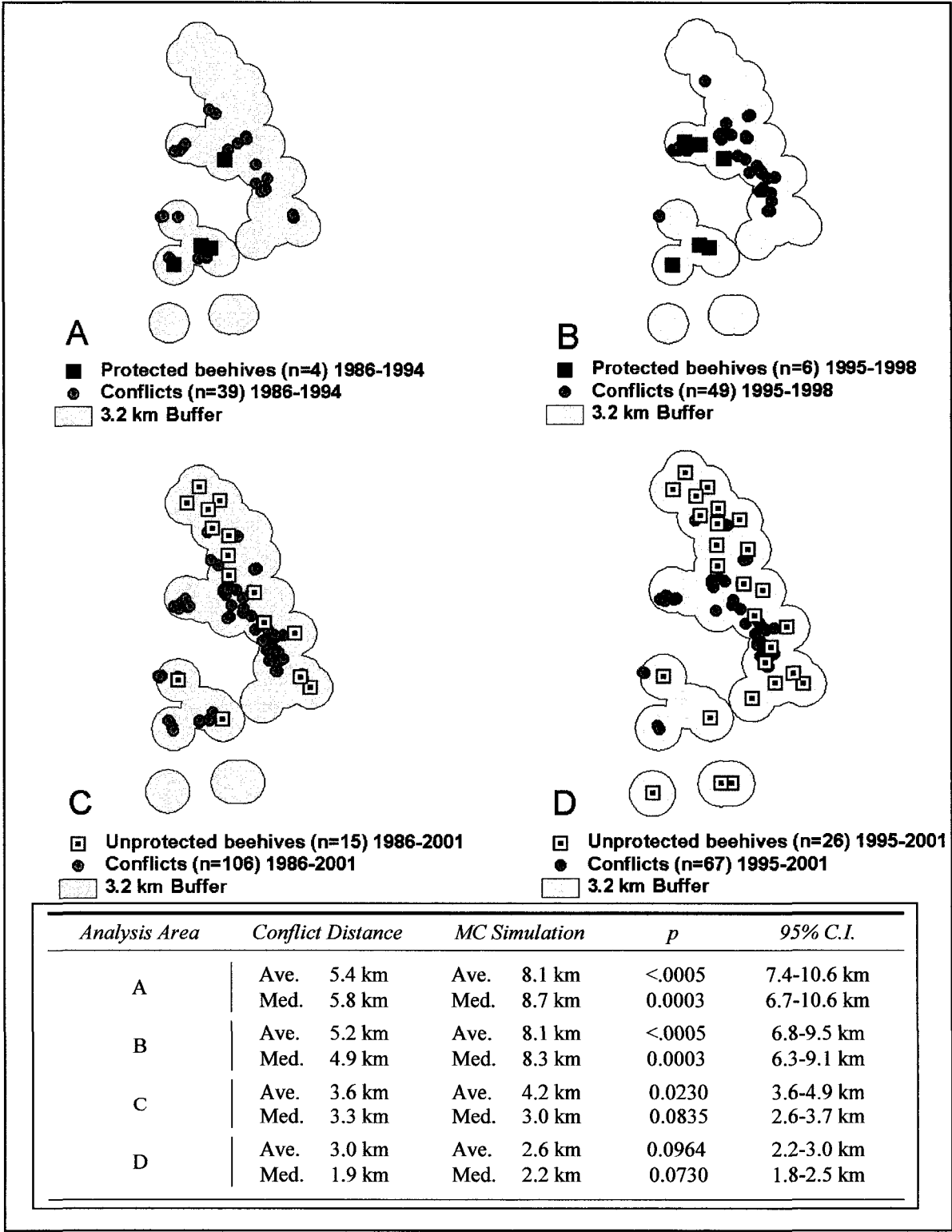


Figure 6.12. Average and median distances of conflicts and MC simulations to nearest protected and unprotected beehives in the 3.2 km buffer.

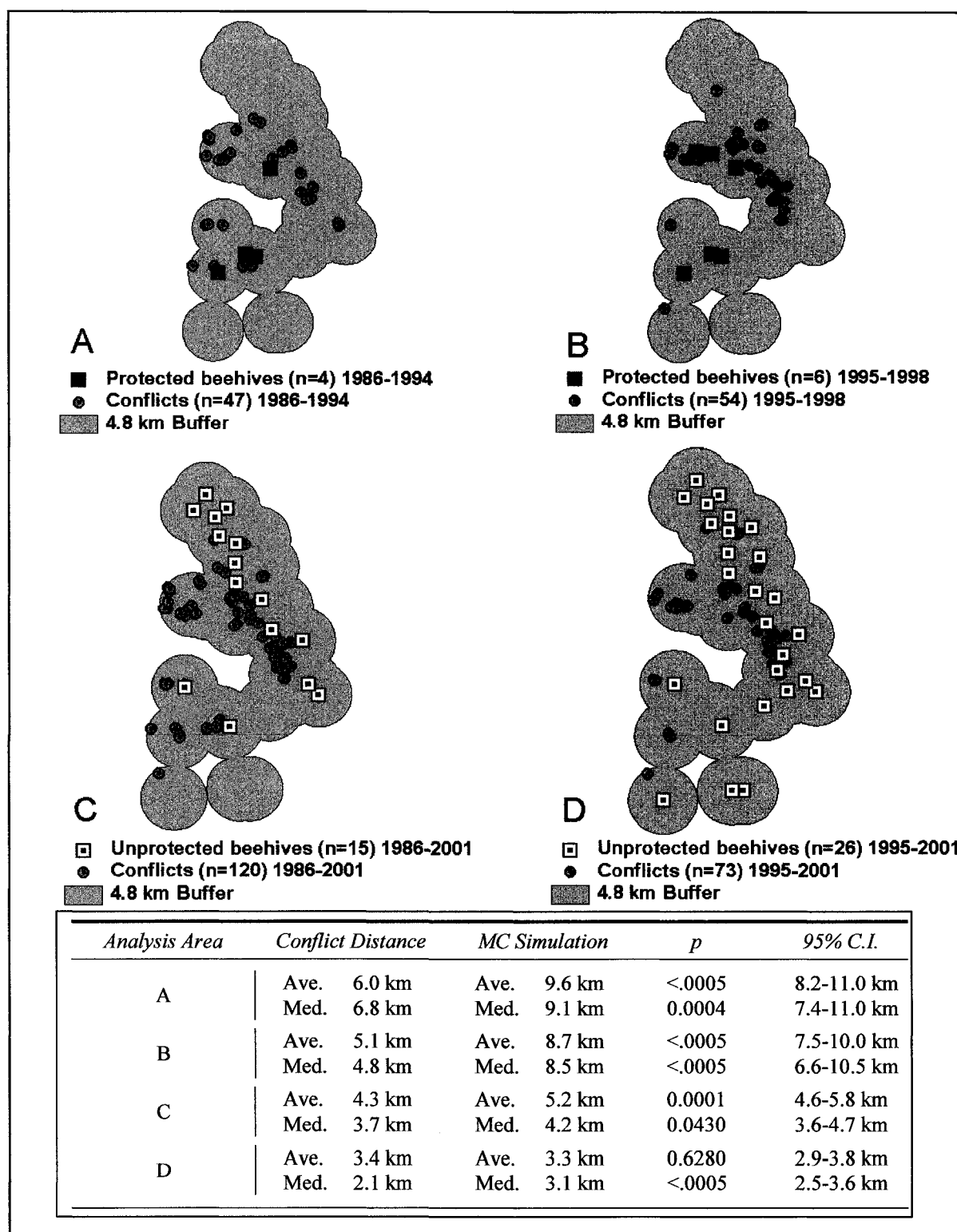


Figure 6.13. Average and median distances of conflicts and MC simulations to nearest protected and unprotected beehives in the 4.8 km buffer.

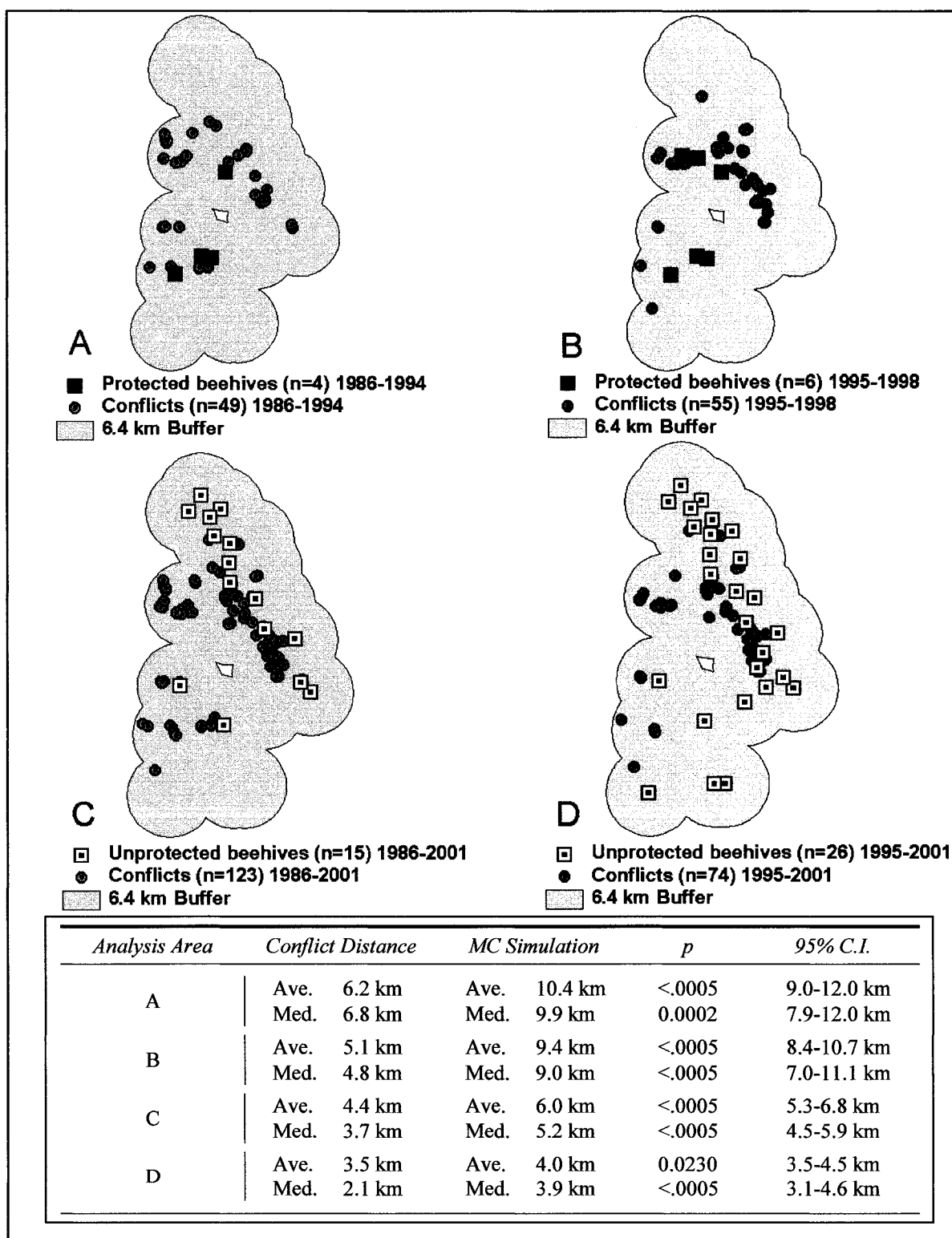


Figure 6.14. Average and median distances of conflicts and MC simulations to nearest protected and unprotected beehives in the 6.4 km buffer.

Beehive Protection Status at Three Different Buffer Sizes

Conflicts were positively associated with all types of beehives in all three buffers during all tested time intervals (Figures 6.12, 6.13, and 6.14). It was evident that more conflicts were near protected beehives than would have been expected. This pattern was found in all three buffers.

Beehive Protection Status and Conflict Likelihood

As a supplement to the MC analysis of beehive data, we used a chi-square test to determine if protection status affected the probability of conflicts using only known beehive conflicts for three different sized buffers. Protected beehives were less likely to be associated with conflicts than were unprotected beehives for the 3.2 km buffer ($\chi^2 = 7.29$, $p = .026$, $df = 2$), but were only mildly less likely with the 4.8 km buffer ($\chi^2 = 5.69$, $p = .058$, $df = 2$) and 6.4 km buffer ($\chi^2 = 5.07$, $p = .079$, $df = 2$) (Table 6.12).

Table 6.12. Observed and expected counts (in parentheses) and totals of conflicts for protected and unprotected beehives during 1986-2001 in 3.2 km, 4.8 km, and 6.4 km buffers.

<i>Beehive Conflict History</i>				
<i>Protection Status</i>	3.2 km Buffer	No	Yes	Totals
	Protected	7 (3.88)	0 (3.11)	7
	Unprotected	8 (11.11)	12 (8.88)	20
	Totals	15	12	27
<i>Protection Status</i>	4.8 km Buffer	No	Yes	Totals
	Protected	7 (4.29)	0 (2.70)	7
	Unprotected	12 (14.70)	12 (9.29)	24
	Totals	19	12	31
<i>Protection Status</i>	6.4 km Buffer	No	Yes	Totals
	Protected	7 (4.45)	0 (2.54)	7
	Unprotected	14 (16.54)	12 (9.45)	26
	Totals	21	12	33

Riparian and Wetland Associated Vegetation Buffers

The proportions of conflicts within riparian and wetland associated vegetation was much greater than expected given the availability of this habitat within the study area. Additionally, disproportionately more conflicts occurred within the 200 m, 750 m, and 2000 m buffers of the riparian and wetland associated vegetation than expected by the relative size of these buffers in the study area (Figure 6.15).

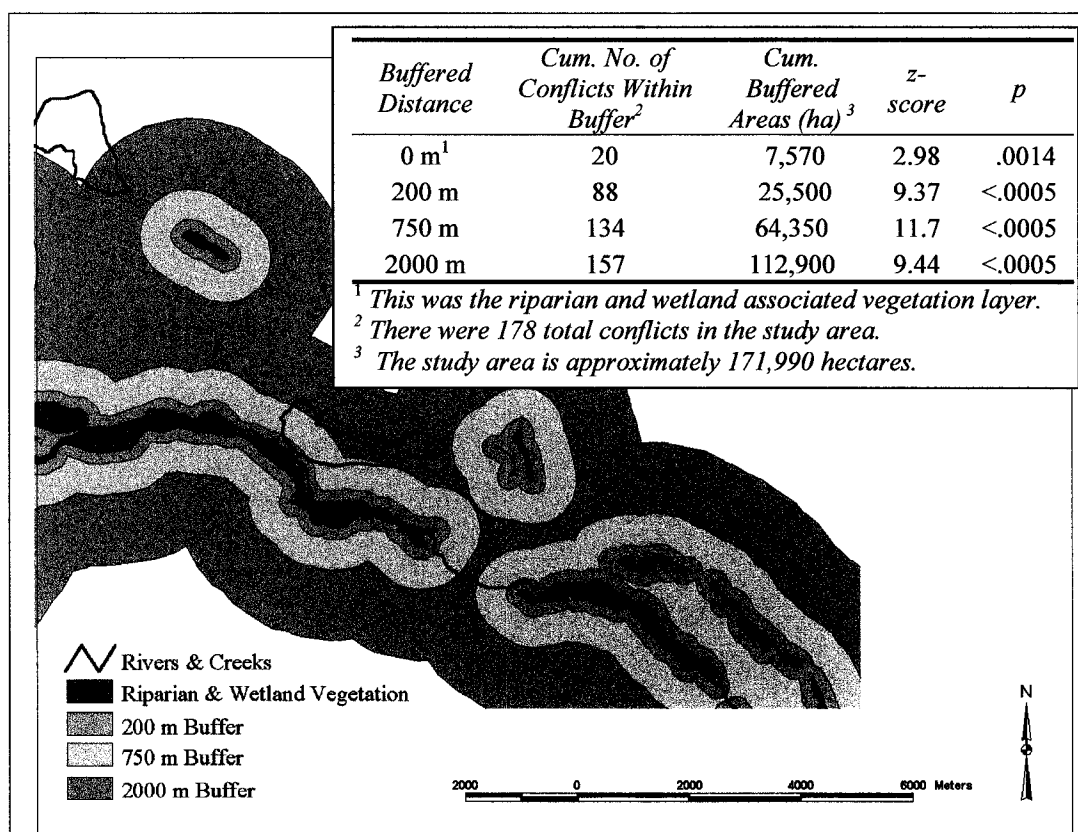


Figure 6.15. Riparian and wetland associated vegetation layer with buffers that contain approximately one-half, three-fourths, and seven-eighths of all conflicts with table of z-test results.

Nearly half of the cumulative proportion of conflicts occurred within a 200 m buffer of riparian and wetland associated vegetation (Table 6.13) and conflicts occurred at a higher rate in riparian and wetland associated areas than would be expected under an assumption of spatial randomness.

Table 6.13. Buffered distances, cumulative number of conflicts within buffers, cumulative proportion of conflicts in buffers, cumulative area of buffers, and cumulative proportion of buffers in study area¹.

<i>Buffered Distance²</i>	<i>Cum. No. of Conflicts Within Buffer</i>	<i>Cum. Proportion of Conflicts in Buffer</i>	<i>Cum. Area of Buffer(ha)</i>	<i>Cum. Proportion of Buffer in Study Area</i>
0 m	20	0.11	7,570	0.04
200 m	88	0.49	25,500	0.15
250 m	99	0.56	29,540	0.17
500 m	123	0.69	48,160	0.28
750 m	134	0.75	64,350	0.37
1000 m	140	0.79	78,100	0.45
1250 m	145	0.81	89,440	0.52
1500 m	147	0.83	98,740	0.57
1750 m	151	0.85	106,430	0.62
2000 m	157	0.88	112,900	0.66
2250 m	161	0.90	118,570	0.69
2500 m	162	0.91	123,430	0.72
2750 m	169	0.95	127,880	0.75
3000 m	172	0.97	131,920	0.77

¹ A chi-square test of 7 discrete distance intervals using the above buffers (≤ 0 m, 0-200 m, 200-500 m, 500-1000 m, 1000-2000 m, 2000-3000 m, >3000 m) resulted in highly significant differences in observed numbers of conflicts within the discrete intervals given the proportion of buffers within each of the intervals ($\chi^2 = 196.89$, $p < .0005$, $df=6$). The most striking differences were among the observed versus expected values in the distance intervals ≤ 0 m, 0-200 m, and 200-500 m.

² The 0 m buffer was the riparian and wetland associated vegetation polygon layer(polygons were pooled).

DISCUSSION

Seasonal conflict density maps illustrate the relative locations and scale at which a majority of conflicts occurred during 1986-2001. After accounting for seasonal overlap among hotspots, we found that a small proportion of the study area ($\approx 8\%$) was made up of the seasonal conflict hotspots. Seventy five percent of all conflicts were found in the hotspots (A-S) we defined and identified and more than a half (58%) of all conflicts were found in the chronic hotspots we defined. There was also distinct spatial overlap among chronic hotspots. We recognize that an *a priori* definition of hotspots will influence results. However, we also identified hotspots by using a 2-conflict threshold versus at least 3 conflicts with the same time threshold (at least 2 years of total conflict) and found that this exercise added 12 additional conflicts to our analysis. Subsequently, we felt

justified in using at least 3 conflicts threshold for establishing the context of conflict hotspots.

Based on our definitions and analysis, hotspot locations varied depending on season. Spring and fall hotspots were more clustered along river and creek bottoms while summer hotspots were more dispersed throughout the study area. Grizzly bears tend to make extensive use of available riparian vegetation for movement, security, and seasonal foraging (spring and fall) in the study area (Aune and Kasworm, 1989). This important habitat component coupled with the availability of seasonal attractants may have in part, led to the patterns we observed. However, there was spatial overlap among many hotspots suggesting that a possible combination of landscape features and year-round attractants that are found across seasons led to hotspot formation. This was particularly evident in chronic hotspots that we identified and suggests that repeated availability of human attractants may lure grizzly bears into conflict situations over several years leading to consistent contact with humans. It was beyond the scope of this study to determine the fate of individual grizzly bears associated with conflicts within hotspots, but it is reasonable to propose that hotspots are areas where repeated conflicts can lead to “nuisance status” classification and subsequent trapping, relocation, and eventual killing of bears by wildlife authorities based on current management guidelines (IGBC, 1986). The genesis of conflicts within hotspots in the study area is important in terms of landscape scale context. A hotspot that may lead to a specific “offense” or strike being counted against a particular bear has consequences for grizzlies whose wide ranging habitat requirements might lead a particular bear into conflicts outside the study area where it might receive another “offense” that counts towards the eventual management

decision for removal from the population. Hotspots were not the product of a few “problem bears” but likely a product of landscape features and specific attractants that lead to problematic contexts within the study area landscape. Recall that 22 individual grizzly bears were positively identified and associated with seasonal hotspots. Despite the fact that 92 conflicts found within all seasonal hotspots (n=133) were not identified with specific grizzly bears, MFWP Grizzly Bear Management Specialist, Michael J. Madel (per. comm. October 15, 2002) has suggested that the most recent six-year running average counts of females with cubs along the Rocky Mountain Front is approximately 145 bears and that ≈ 50 individual grizzly bears likely use the study area boundary in a given year. Thus, it is highly likely that more than 22 individual grizzly bears came into conflicts with human activities within the seasonal hotspots.

Seasonal conflict hotspots also help categorize the type of conflicts that make up the majority of conflicts that are found in discrete spatial locations and occur seasonally. Spring conflicts within the hotspots we identified tended to be residential, close proximity conflicts and livestock depredations. Summer conflicts within hotspots were generally associated with livestock depredations and beehives. The bulk of fall conflicts within hotspots were residential, close proximity conflicts and livestock depredations. Seasonal conflict density mapping may assist wildlife managers by targeting their management to spatially discrete areas and may help managers anticipate the general types of conflicts that may occur so that proactive management actions can take place (see Chapter 8 for a more detailed discussion on management recommendations).

Although we knew about the general types of conflicts that occurred during 1986-2001 and we knew that river and creek bottoms and riparian area vegetation was a highly

relevant landscape feature in understanding locations of conflicts since agricultural activities tend to be concentrated here, the point of establishing the context of conflict hotspots was to identify why some areas of the study area with attractants like livestock or bone yards had high densities of conflicts while others with these same attractants had few if any conflicts. In fact, simply knowing the type of conflict does not necessarily help explain the general spatial patterns of hotspots that account for the majority of conflicts. It appears that hotspots may be a result of the presence of common landscape features and a set of specific attractants that are found in spatial proximity to one another. A majority of seasonal hotspots shared the following features and attractants in common: 1) riparian and wetland associated vegetation, 2) proximity to river or creek, 3) presence of bone yards, and 4) presence of beehives. We also found that in hotspots with distinct spatial overlap, riparian vegetation, and year-round attractants like beehives and bone yards were all found in close proximity to one another. These overlapping hotspots accounted for 62% of all conflicts.

Certainly seasonally available attractants like calving and lambing areas, or spring, summer, or fall sheep and cattle pastures are critical components of seasonal hotspots and influence the likelihood of conflicts. Yet, there are numerous places throughout the study area where there are landscape features and many attractants that one would expect to lead to conflicts. It was not self-evident that simply presence of bear habitat and the presence of livestock were necessary for conflicts to arise. Using the spring conflict hotspot map as an example, it is apparent that there are calving areas, bone yards, and spring cattle pastures near one another in riparian areas, but few if any conflicts in these places (Figure 6.16). Apparently, these places while providing habitat

for bears and having an abundance of attractants, do not have the same collection of landscape features and groups of attractants that led to the formation of the spring hotspots that accounted for 73% of all spring conflicts ($n=93$) during 1986-2001. Similar patterns are evident in the summer and fall conflict hotspot maps (Figure 6.6, Figure 6.8).

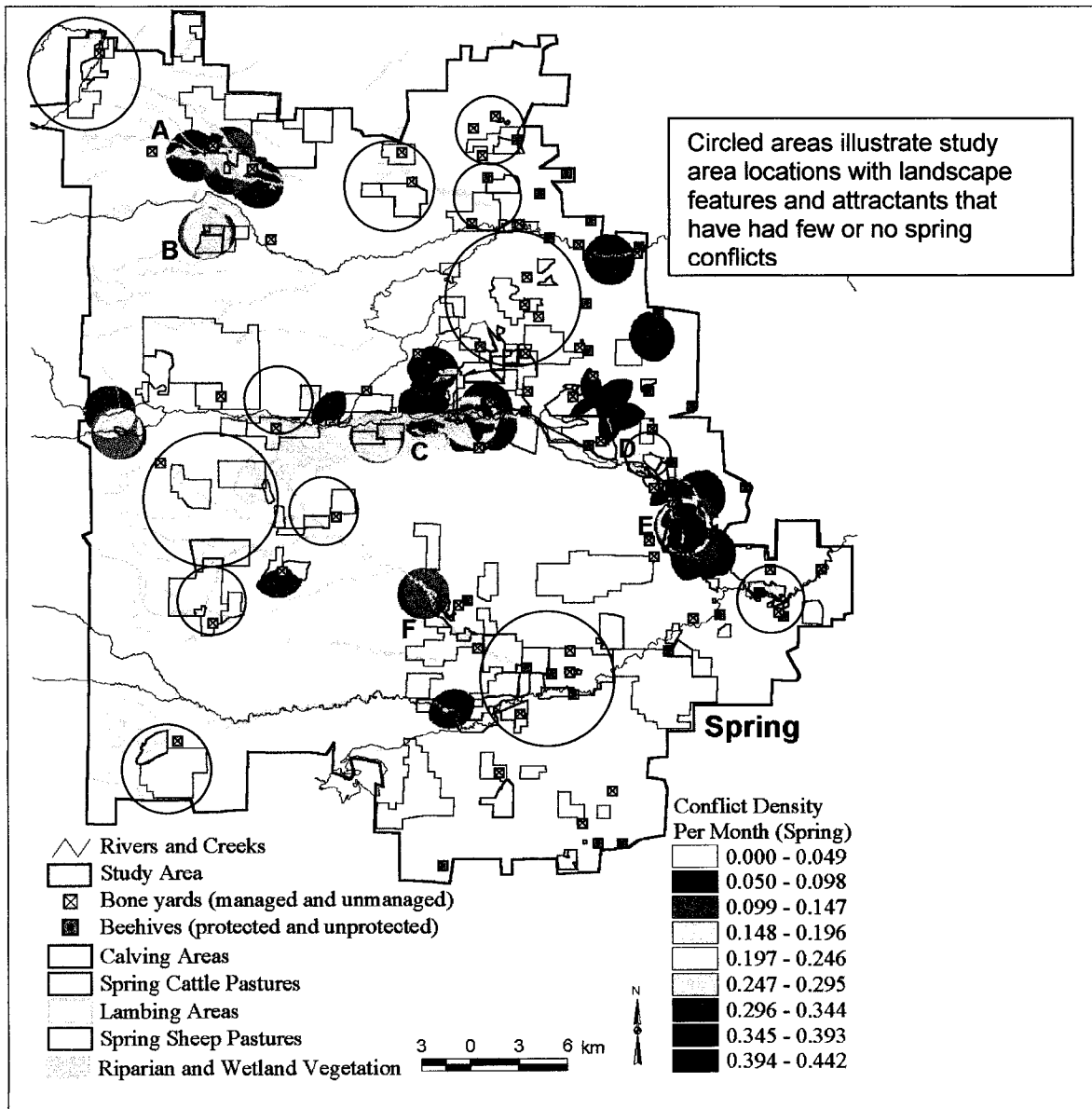


Figure 6.16 Spring isopleth conflict densities for hotspots A-F ($n/\text{km}^2/\text{month}$; $n=93$) with landscape features and seasonally available attractants.

All of this indicates the need to simultaneously consider the effects of landscape features and attractants on human-grizzly conflicts through an appropriate model.

Riparian and wetland vegetation, rivers and creeks, and the locations of bone yards were features and attractants found in the majority of hotspots across all seasons and were statistically significant in Z-tests and MC simulations. Beehives were another attractant common to the majority of seasonal hotspots and in 14 of the 19 hotspots identified across seasons; unprotected beehives were present during 1986-2001. While the MC simulations of beehive protection status were partially inconclusive, our chi-square analysis of only beehive related conflicts and protected and unprotected beehives at three different buffers suggested that there was moderate evidence that unprotected sites are more likely to result in conflicts than protected beehives in a 3.2 km buffer of beehives that had experienced conflict.

It should be noted that results from this analysis of hotspots pertain to the period 1986-2001. The longevity of the hotspots we identified may depend, in part, on changes in availability of attractants. We knew that some livestock producers stopped raising sheep after they experienced multiple conflicts over multiple years in one of the overlapping conflict hotspots. Additionally, one operator installed an electric fence around his sheep lambing and bedding areas that should non-lethally deter grizzly bears. Bone yards that are part of the Montana Department of Fish, Wildlife and Park's redistribution program are likely less of an attractant than unmanaged bone yards and may affect the longevity of conflict hotspots. Other preventative management actions by livestock producers and or Montana Fish, Wildlife and Parks may affect the long-term existence of hotspots.

These univariate results are helpful in addressing the likelihood that the locations of landscape features and attractants and conflicts do not appear to be random. Recall that locations of calving areas and spring cattle pastures showed strong spatial associations with spring conflict locations throughout the study area. There were also strong associations among bone yard locations and all conflicts and moderate evidence that unprotected beehives were more likely to experience grizzly bear damage. Additionally, sheep lambing areas and spring, summer and fall pasture locations showed strong associations with conflicts in those same seasons. However, these tests were carried out on a variable-by-variable basis and should be tempered by that fact that univariate analyses can not adequately account for the confounding effects of multiple features and attractants like the presence of calving areas, sheep pastures, unprotected beehives, and bone yards (carcass dumps) that might all be located in close proximity to riparian areas and be found across seasonal hotspots. Nor can the analysis at present address the *relative strength* that features and attractants might play in assessing the likelihood of conflicts at the seasonal or annual time frames. For example, it might be that simply being in a riparian with *any* one attractant is enough to lead to conflict. To simultaneously measure the relative strengths of attractants within riparian zones, these variables need to be considered collectively. Additionally, Monte Carlo (MC) tests did not adequately account for temporal changes in management practices like beehive protection status or bone yard management. Further analysis such as a multivariate model using logistic regression is a useful means to address the cumulative and interactive effects of attractants that are most strongly associated with conflicts. For example, calving areas were found in all spring hotspots and conflicts were tightly

clustered inside calving areas in hotspots like C and D. However, there were also sheep lambing areas in half of the spring hotspots, and in five out of six spring hotspots there were spring sheep pastures. After accounting for the strong influence of riparian vegetation on the locations of conflicts, it would be important to assess *how* and *if* the multiple attractants above contribute differentially to the likelihood of conflict through multivariate models.

CONCLUSIONS

We have presented evidence that riparian and wetland associated vegetation, rivers and creeks, and the locations of a suite of agricultural-based attractants are associated with seasonal conflict hotspots. Hotspots tended to be clustered along river and creek bottoms and conflicts occur chronically in these areas. There were common attractants, namely bone yards and beehives that were found in the majority of all hotspots across all seasons. It appears that hotspots may be a product of a specific set of common attractants that occur in close proximity to one another. We found many areas across all seasons that had a variety of features and attractants but few if any conflicts. Further analysis is warranted to determine the relative additive and/or interactive strength that different attractants exert on the likelihood of conflict and if a specific suite of attractants found near one another are associated with conflict hotspots.

CHAPTER 7: FACTORS ASSOCIATED WITH HUMAN-GRIZZLY BEAR CONFLICTS ON PRIVATE AGRICULTURAL LANDS: RESULTS OF MULTI VARIABLE LOGISTIC REGRESSION MODELS

ABSTRACT

We present an exploratory logistic regression modeling approach to assess how landscape features and agricultural related attractants contributed to the probability of human-grizzly bear conflicts on private agricultural land. We explored the spatial associations among reported human-grizzly bear conflicts during 1986-2001 with livestock pasture locations, bone yard locations, and beehive locations; and accounted for broad vegetative conditions along the Rocky Mountain Front, Montana. We conducted a survey of 61 livestock related land users in north-central Montana in the upper Teton watershed and collected spatial and temporal data on livestock pasture arrangements and beehive site locations from 1986-2001. We accounted for changes in livestock management and beehive site locations and protection status for each season of each year for the study time frame. We used random points ($n=2032$) to serve as available locations in the study area for logistic regression model analysis. We used Akaike's Information Criteria (AIC) and Hosmer-Lemeshow goodness-of-fit statistics for model selection and produced three final seasonal models and an overall annual model based on the selection criteria. We also produced contour probability plots using the inverse logit transformation to assess the predictive capability of models. We found that the presence of riparian vegetation, the minimum distance to spring, summer, and fall sheep or cattle pastures, calving areas and sheep lambing areas, unmanaged bone yards, and fenced and unfenced beehives are all associated with the likelihood of human-grizzly bear conflicts.

INTRODUCTION

Humans cause most grizzly bear deaths in the Rocky Mountains of Canada and the contiguous United States (US). From 1974 to 1996, 85% of known deaths of bears that were radio-marked in southern Canada and the contiguous US were attributed to humans (Mattson et al. 1996). These deaths were often preceded by conflicts with people. Removals of “nuisance” and/or habituated grizzly bears are a leading cause of death in many populations (Mattson, 1998; Boyce et al. 2001a).

Grizzly bear deaths in the US tend to be concentrated on the periphery of core habitats where human activities overlap with grizzly bear range (U.S. Fish and Wildlife Service, 2003). Even in relatively large ranges such as the one centered on Yellowstone National Park, a source-sink dynamic exists that is driven by annual variation in availability of a key food (whitebark pine seed [*Pinus albicaulis*]; Pease and Mattson, 1999). Grizzly bear mortality doubled during years when few seeds were available as bears foraged in human dominated habitats that often contain attractants that lead to increased conflicts with humans (Mattson et al. 1992). These less secure, peripheral low elevation habitats in the western United States are typically privately owned or leased agricultural lands (Servheen, 1998).

In Montana, researchers and managers have called for reduced availability of anthropogenic food sources and attractants on privately owned lands to reduce conflicts and mortalities of especially female grizzly bears (Mace and Waller, 1998; Madel 1996). This is particularly important as grizzly bear populations show preliminary signs of growth and range expansion outside of core habitats such as Yellowstone National Park (Boyce et al., 2001b; Schwartz et al., *In press*). Conflicts are inevitable when grizzlies

use low elevation habitats dominated by human uses. Interactions among grizzly bears and humans on private agricultural lands and the factors predisposing grizzly bears to risk of conflict have not been thoroughly investigated. The most similar type of research we have found is by Mech et al. (2000) who studied characteristics of Minnesota farms that had experienced chronic cattle losses to wolves with matched farms without conflict. Our work focuses on understanding the spatial associations among a variety of landscape features, agricultural attractants, and reported human-grizzly bear conflicts during 1986-2001.

In this chapter, landscape features refer to vegetation and attractants refer to the locations of seasonal livestock pastures, bone yards (carcass dumps), and/or beehives. Conflicts refer to incidents reported to MT Fish, Wildlife and Parks (MFWP) during 1986-2001 involving grizzly bears and human activities. We specifically assess how landscape features and attractants are spatially associated with the likelihood of conflicts using logistic regression with Akaike's Information Criterion (AIC) and Hosmer-Lemeshow goodness-of-fit statistics for model selection for three seasonal models and an annual model for the time period 1986-2001.

PURPOSE OF MODEL

The models that we present reflect an exploratory modeling approach to help explain associations among landscape features, attractants, and conflicts (Lunneborg, 1994). Logistic regression is a widely recognized statistical method that has been used in wildlife research, health sciences, social sciences, and many other disciplines to describe the relationships among several explanatory variables and a binary response (Hosmer and Lemeshow, 2000; Pereira and Itami, 1991; Demaris, 1992; Pampel, 2000). In our case,

we used reported grizzly bear conflicts and random points to serve as presence and absence of conflict for the response variable despite having knowledge about some the general types of conflicts. For example, we knew prior to any model building that approximately 17% of conflicts during 1986-2001 were beehive related. We also knew that conflicts tended to be in close proximity to riparian vegetative cover types. Our rationale for using these data was to help explain to what extent, if at all, the types and locations of landscape features and multiple attractants that were *associated with conflicts*. Most importantly, we wanted to control for biophysical landscape features like riparian vegetation and evaluate the relative importance that agricultural attractants have in contributing to conflicts *after accounting for the effects of riparian vegetation*.

In prior analysis (see Chapter 6), we found evidence of discrete seasonal conflict hotspots where conflicts appeared to be associated with a common set of landscape features and attractants found in close proximity to one another. A majority of these seasonal conflict hotspots shared the following: 1) the presence of riparian and wetland associated vegetation, 2) spatial proximity to a river or creek, 3) the presence of bone yards, and 4) the presence of beehives. Seasonal hotspots also had unique attractants like the presence of calving areas that were only available in the spring. However, there was *considerable spatial overlap* in many of the hotspots (see Chapter 6, pg. 114 and Figures 6.3, 6.5, 6.7). In other words, it appeared that a specific combination of landscape features and attractants found in close proximity to one another that were found across seasons contributed to the formation of spatially distinct hotspots. There was clear evidence that year-round attractants like unmanaged bone yards and unfenced beehives that were found in close proximity to one another were found in nearly all seasonal

hotspots that shared distinct spatial overlap. In fact, we found that 62% of all conflicts were found in seasonally overlapping hotspots that contained beehives and bone yards.

However, the availability of attractants in the study area landscape was dynamic. Consider that: 1) types of livestock changed, 2) locations of livestock changed seasonally, 3) bone yards had different amounts of available carrion, 4) beehive sites were developed, and 5) beehives changed from being unfenced to fenced to protect against grizzly bear damage all over the 16 year study time frame. Our prior analysis in Chapter 6 did not adequately account for temporal changes in management practices like those mentioned above. The univariate analysis that we undertook in Chapter 6 also could not adequately account for the confounding effects of multiple features and attractants like the presence of calving areas, sheep pastures, unprotected beehives, and bone yards (carcass dumps) that might all be located in close proximity to riparian areas and be found across seasonal hotspots. Separately, many of the above attractants were spatially associated with conflicts and conflict hotspots, but it was unclear whether this association was due to a specific type of attractant or some other spatially proximate factor. Nor could our previous analysis address the *relative strength* that features and attractants might play in assessing the likelihood of conflicts at the seasonal or annual time frames after accounting for the strong influence of riparian areas. Logistic regression is a useful tool to measure the cumulative effects of landscape features and attractants that are most strongly associated with conflicts. We recognize that there is a level of dependency between conflicts and beehives or conflicts and calving areas, but a key purpose of this exploratory modeling effort seeks to explain whether *it is a collection of attractants* that are spatially associated with distinct patterns of conflicts. As we attempted to illustrate in

Chapter 6, we knew that conflicts were associated with livestock depredations or beehives, but we wanted to know why these patterns of conflicts occurred in some discrete locations with cattle or beehives more so than others. To accomplish this we needed to account for landscape features and multiple attractants that have changed over time and attempt to establish what constitutes conflict hotspots.

A second key purpose of this modeling effort is to visually display conflict probabilities based on the inverse logit transformation of the seasonal and annual logistic models. This can be done using a contour probability plot of conflict probabilities that are represented by isopleths much like a weather map that might display contours of cooler and warmer temperatures. In this case, the contours or isopleths represent continuous probabilities of conflict across a landscape. This visual display of model results has particular relevance for wildlife management efforts by clarifying the relative scale at which human-grizzly bear conflicts occur and by guiding specific management effort to specific places in a landscape. Contours greater than a threshold such as .5 can focus management efforts to areas where there is a greater likelihood of conflict. Conflict probability plots also provide a logical means to direct further inquiry to less tangible factors associated with conflicts like human attitudes towards bears and specific animal husbandry practices in locations with and without conflicts. Moreover, locations where conflict probabilities are predicted to be high but do not have conflicts may alert wildlife managers to places where people may be having conflicts with grizzlies but not reporting them to authorities, may be engaged in innovative proactive management techniques thus avoiding conflicts, or where malicious killing may occur. Finally, model results from this research may be useful in other similar landscapes as indicators of

important attractants that may be associated with conflicts. Other regions that share similar ecological conditions and agricultural lands uses and have existing grizzly bear populations or expanding populations may benefit from using these types of models. Depending on the quality of existing data on human-bear conflicts, models might be used in a predictive fashion to predict where future conflicts might occur. This could enable wildlife and conservation efforts to take proactive approaches to human-grizzly bear conflict management and prevent conflicts from occurring in the first place.

STUDY AREA

Our 172,000 ha study area is located in north-central Montana known as the Rocky Mountain Front (RMF) and is delineated by the upper Teton River Watershed (Figure 7.1). Because our research focused on private lands, we bounded the study area on the west by the Lewis and Clark National Forest boundary and on the east by the approximate transition from rest-rotation cattle ranches to intensive winter wheat farms. Approximately 80% of grizzly bear spring habitat in this area is found on private lands primarily in fen and riparian habitats. The riparian areas used by grizzly bears provide critical seasonal foraging opportunities, cover, and secure habitats for movement (Aune and Kasworm 1989).

We selected this study site because of the concentration of grizzly bears that make extensive use of privately owned and managed agricultural lands (Aune and Kasworm, 1989). Ranches tend to be located along creeks and river bottoms in this area and unsecured attractants like calving afterbirth, calves, lambs, beehives, or household garbage are common. Concentrated bear use has resulted in large numbers of human-grizzly bear conflicts involving cattle depredation and property damage.

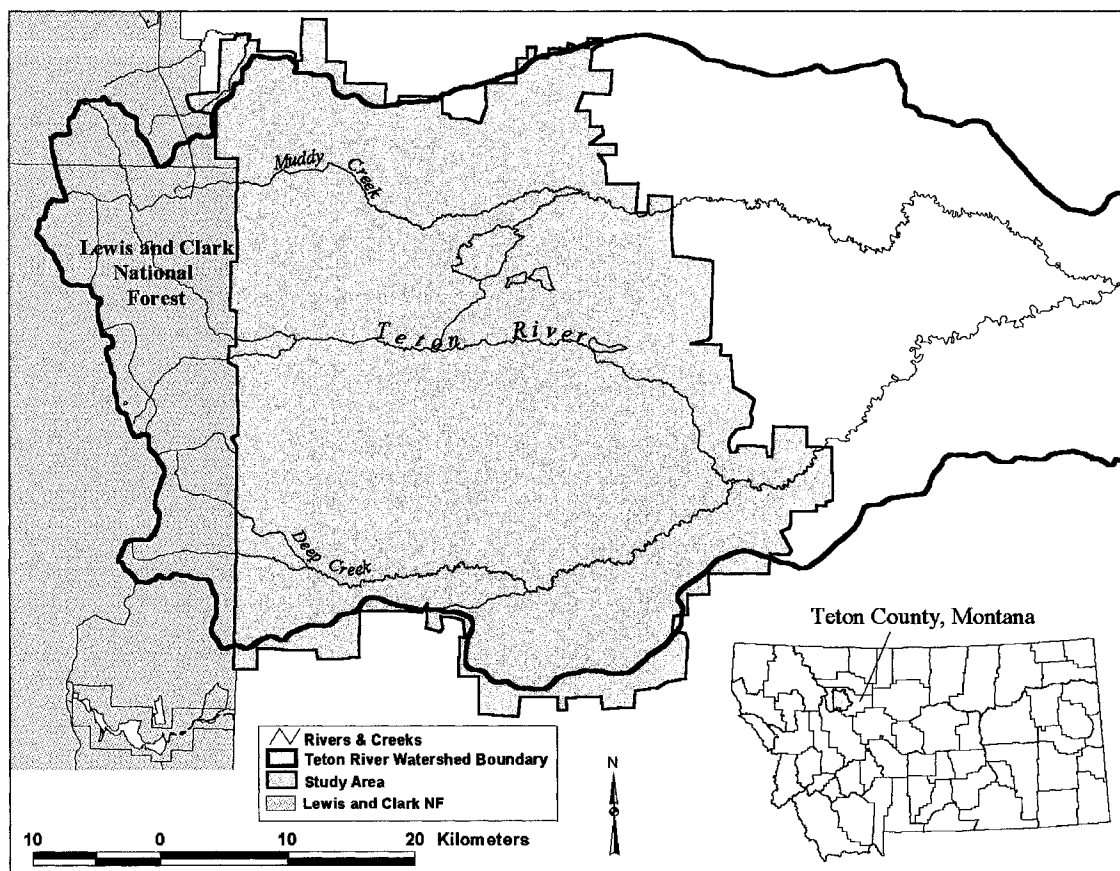


Figure 7.1. Study Area Location in Teton County, Montana.

METHODS

Background on Logistic Regression Model

Response Variables

Logistic regression uses multiple explanatory variables to predict the likelihood of a binary response variable (Demaris, 1992). In this case, our binary response variable was whether a point was a reported human-grizzly bear conflicts (1's) or a random point (0's). Montana Department of Fish, Wildlife and Parks (MFWP) provided us with human-grizzly bear conflict data ($n=178$) from 1986-2001 for the study area boundary. These conflicts included livestock depredations, beehive damage, and other incidents. Since we wanted to produce seasonal and annual models, all reported conflict points were organized by year and season of occurrence into a database. We used the following seasonal definitions based on changes in grizzly bear diets: Spring =den/den vicinity emergence to July 15, Summer =July 16 to September 15, and Fall =September 16 to denning (Craighead et al. 1982; Mace and Jonkel 1983).

Secondly, we randomly generated and located points within the study area to represent “non-conflicts” (0's). This process of random allocation of points or “sampling” to obtain a binary response of a non-occurrence of a phenomenon has been used successfully in recent logistic regression modeling efforts incorporating GIS (Perestrello de Vasconcelos et al., 2001; Boyce et al., 2002). We based our modeling on a sample of 2032 random points. The 2032 points “saturated” the 1720 km² study area in that there was slightly more than one random point per square kilometer. We “resampled” these random points in two stages. The first stage involved re-sampling proportional to the number of confirmed conflicts that occurred in a given year. The

second stage involved re-sampling proportional to the number of confirmed conflicts that occurred in a given season over 16 years based on our seasonal definitions (Spring =52%, Summer =28%, and Fall =20%). In this way, random points represented landscape conditions by year and season in the same proportion as they existed among the observations of human-grizzly bear conflicts.

Model Process, Data Collection, and Variables Used for Model Selection

After each year and all three seasons had the appropriate number of conflict points and random points, we used GIS to attribute each of the conflict points and random points with seasonal and year-round information from variables on landscape features and agricultural attractants. *Seasonal variables* were those that we assumed to be available only during the spring, summer, or fall. *Year-round variables* were those that we felt could have an impact on conflict likelihood across spring, summer, and fall seasons. For landscape feature variables we used vegetative cover types from 30-meter pixel resolution Thematic Mapper Landsat data for northern Idaho and western Montana (Redmond et al. 1996) to account for broad vegetation conditions in our study area. For agricultural attractant variables we collected information on pasture locations, bone yards, and beehives from a survey of 61 of 64 livestock related land users who either owned, managed or leased grazing pastures in the study area. We also collected information from one commercial beekeeper whose beehives were found in the study area. We had one person refuse to participate and could not contact the remaining two. Since we accounted for temporal and spatial changes in livestock types, bone yard management, beehive site development, and beehive fence status seasonally and annually, the resulting database contained 48 separate data layers representing 3 seasons

for the 16 years. During interviews with livestock related land users we asked about all types of livestock raised and seasonal pasture use during the 16 year study time frame to account for those that may have raised sheep periodically or those who switched from one type of livestock to another. We also accounted for changes in bone yard management. Bone yard management refers to the MFWP program where carrion from participating ranches are removed during the spring and randomly redistributed to remote portions of the RMF to provide a protein source for grizzly bears (Madel, 1996). Ranchers began participating at different times during 1986-2001 and we accounted for a bone yard that may have changed from an “unmanaged” to “managed” state based on our interview data and records provided by MFWP. Additionally, we collected information from the resident beekeeper on all beehives found in the study area and documented the year they were developed and if they had been protected with electric fences.

The main point here is that seasonal variable information was only attributed to conflicts and random points based on the season of occurrence. Additionally, any annual changes in livestock types, bone yard management, and beehive development and protection status were accounted for. We present all seasonal and year-round variables used for model selection (Table 7.1) and provide an example below of how seasonal and year-round variables were accounted for when we aggregated all data for the annual model. Seasonal models only used conflicts and random points that occurred by season along with the year-round variables and those unique seasonal variables (Table 7.1). This resulted in having seasonal models with smaller sample sizes (spring (n=93), summer (n=50), and fall (n=35)) and fewer degrees of freedom to estimate the error variance.

Table 7.1. Seasonal and year-round candidate variables used in model selection for spring (1-9, 10-21), summer (1-9, 22-28), fall (1-9, 29-35) and annual models (1-35). Indicator Variables¹ accounted for seasonal variables in the annual model.

<i>Description</i>	<i>Season</i>	<i>Variable Type</i>
Landscape Feature		
1) Percent riparian cover type in 1.6 km search radius (s.r.)	Year-round	Continuous
Agricultural Attractant		
Bone yards		
2) Unmanaged bone yard presence / absence in 1.6 km s.r.	Year-round	Categorical (1/0)
3) Managed bone yard presence / absence in 1.6 km s.r.	Year-round	Categorical (1/0)
4) Distance to nearest unmanaged bone yard (m)	Year-round	Continuous
5) Distance to nearest managed bone yard (m)	Year-round	Continuous
Beehives		
6) Unfenced beehive presence / absence in 1.6 km s.r.	Year-round	Categorical (1/0)
7) Fenced beehive presence / absence in 1.6 km s.r.	Year-round	Categorical (1/0)
8) Distance to nearest unfenced beehive (m)	Year-round	Continuous
9) Distance to nearest fenced beehive (m)	Year-round	Continuous
Livestock		
10) Distance to nearest sheep lambing area centroid (m)	Spring	Continuous
11) In / Out of sheep lambing area	Spring	Categorical (1/0)
12) Distance to nearest spring sheep pasture centroid (m)	Spring	Continuous
13) In / Out of spring sheep pasture	Spring	Categorical (1/0)
14) Distance to nearest spring cattle calving area centroid (m)	Spring	Continuous
15) In / Out of cattle calving area	Spring	Categorical (1/0)
16) Distance to nearest spring cattle pasture centroid (m)	Spring	Continuous
17) In / Out of spring cattle pasture	Spring	Categorical (1/0)
18) Presence/absence of spring cattle pasture within 1.6 km s.r.	Spring	Categorical (1/0)
19) Presence/absence of spring sheep pasture within 1.6 km s.r.	Spring	Categorical (1/0)
20) Minimum distance to lambing area or calving area centroid (m)	Spring	Continuous
21) Minimum distance to spring sheep or cattle pasture centroid (m)	Spring	Continuous
22) Distance to nearest summer sheep pasture centroid (m)	Summer	Continuous
23) In / Out of sheep summer sheep pasture	Summer	Categorical (1/0)
24) Distance to nearest summer cattle pasture centroid (m)	Summer	Continuous
25) In / Out of summer cattle pasture	Summer	Categorical (1/0)
26) Presence / absence of summer sheep pasture within 1.6 km s.r.	Summer	Continuous
27) Presence / absence of summer cattle pasture within 1.6 km s.r.	Summer	Continuous
28) Minimum distance to nearest summer sheep or cattle pasture ctrd.	Summer	Continuous
29) Distance to nearest fall sheep pasture centroid (m)	Fall	Continuous
30) In / Out of fall sheep pasture	Fall	Categorical (1/0)
31) Distance to nearest fall cattle pasture centroid (m)	Fall	Continuous
32) In / Out of fall cattle pasture	Fall	Categorical (1/0)
33) Presence / absence of fall sheep pasture within 1.6 km s.r.	Fall	Categorical (1/0)
34) Presence / absence of fall cattle pasture within 1.6 km s.r.	Fall	Categorical (1/0)
35) Minimum distance to nearest fall sheep or cattle pasture centroid	Fall	Continuous

¹Summer Indicator Variable: I_{SU}, Fall Indicator Variable: I_{FA}

The annual model used all conflicts (n=178), accounted for seasonally specific variables, and due to a larger sample size, was able to provide better parameter estimates due to smaller standard errors.

Accounting for Seasonal Variables in the Annual Model

We used indicator variables in the annual model to account for seasonal variables that we assumed had association only with specific seasonal conflicts. We wanted to accommodate seasonally different attractants like distance of a spring, summer, and fall cattle pasture to nearest conflict but only include measurements in the annual model equation that were season-specific. In other words, we did not want summer or fall cattle pasture distance measurements contributing any information to conflicts that occurred in the spring. Recall that conflicts and random points in the database were organized and allocated by year and into spring, summer, and fall seasons for all 16 years. For example, spring conflicts that occurred in 1997 were *only being modeled by those variables that were seasonally available at that particular location in the study area and in that year.*

We first illustrate what partial model equations look like for an example of one seasonal variable and one year-round variable if *only spring, summer, and fall models* are run. We then show how *only the annual model* equation accommodates these same example variables. In this hypothetical example, the spring seasonal variable is “distance to spring cattle pasture centroid” and the year-round variable is “percent riparian cover type in a 1.6 km search radius” (Table 7.1). We have shortened “distance to spring cattle pasture centroid” to “**distance spring cattle**” and “percent riparian cover type in a 1.6 km search radius” to “**percent riparian**” for clarity. In the summer and fall seasonal model

equations below, “distance to summer cattle pasture centroid” (“**distance summer cattle**”) and distance to fall cattle pasture centroid (“**distance fall cattle**”) are evident. We demonstrate how these variables are eliminated by using indicator variables when, in this example, we only want a distance measure for spring cattle pastures to the nearest spring conflict.

Suppose we have the following 3 seasonal models:

$$\text{Spring: } \text{logit}(y) = \beta_0 + \beta_1 * \text{distance spring cattle} + \beta_2 * \text{percent riparian} + \varepsilon$$

$$\text{Summer: } \text{logit}(y) = \gamma_0 + \gamma_1 * \text{distance summer cattle} + \gamma_2 * \text{percent riparian} + \varepsilon$$

$$\text{Fall: } \text{logit}(y) = \delta_0 + \delta_1 * \text{distance fall cattle} + \delta_2 * \text{percent riparian} + \varepsilon$$

Where $y = (1 \text{ if the point is a conflict, } 0 \text{ otherwise, } \varepsilon = \text{residual error})$

The annual model below combines these seasonal model equations with the addition of summer (I_{SU}) and fall (I_{FA}) indicator variables in the dataset defined as:

$I_{SU} = [1 \text{ if observation is in summer, } 0 \text{ otherwise}]$

$I_{FA} = [1 \text{ if observation is in fall, } 0 \text{ otherwise}]$

The annual model is then:

$$\begin{aligned} \text{Annual Model: } \text{logit}(y) = & \beta_0 * (1 - I_{SU}) * (1 - I_{FA}) + \gamma_0 * I_{SU} + \delta_0 * I_{FA} \\ & + \beta_1 * \text{distance spring cattle} * (1 - I_{SU}) * (1 - I_{FA}) \\ & + \gamma_1 * \text{distance summer cattle} * I_{SU} + \delta_1 * \text{distance fall cattle} * I_{FA} \\ & + \beta_2 * \text{percent riparian} + \dots + \varepsilon \end{aligned}$$

In this example, if an observation (conflict or random point) occurred in the *spring*, then $I_{SU} = 1$ and $I_{FA} = 0$. Inserting the zeros for the indicator variables and solving simplifying the annual model above results in:

$$\text{Annual Model: } \text{logit}(y) = \beta_0 + \beta_1 * \text{distance spring cattle} + \beta_2 * \text{percent riparian} + \varepsilon,$$

which is just the spring model given earlier. Thus, the only seasonal variable contributing to the annual model in this example would be “**distance spring cattle.**” “**Percent riparian**” remains in the model equation since it is considered a year-round variable. The use of indicator models accounted for all variables that had distance metrics in the annual model.

Presence / absence data for variables were less complicated to account for than continuous variables like distances and we simply “hard coded” or manually adjusted these variables in the database. For example, we assumed that cattle calving areas did not affect conflicts in the summer or fall and assigned zeros to all summer and fall conflicts under the database column titled “In / out of cattle calving area.” This was done to avoid having missing data in all of our variable columns in the annual model database. This allowed the logistic regression model to function properly using all presence / absence seasonal variables with 1’s or 0’s based only on the season in which they occurred.

Representation of the Available Landscape

The use of random points in logistic regression models is inherently problematic as these points represent availability instead of absence of some attribute. However, we used random points because we felt that the alternatives were overly complex. We contemplated using a grid or lattice-based model where assigned grid cells would have a the binary response (1 or 0 based on whether a conflict occurred in that specific grid cell). This has intuitive appeal since one can directly account for those grid cells where conflicts occurred versus grid cells without conflicts. However, the main issue we faced was that the attractant data we had on livestock pasture locations would have bisected grid cells requiring a complicated protocol to assign proportional values to the grid cell.

It was also unclear how a specific grid cell would be treated over the 16-year study time frame or by season. We felt that instead of trying to assign changing values to grid cells over time, that it was simpler to create three seasonal layers for each year that changed over time and attribute those conflicts and random points found in each season of each year. Thus, we choose to use random points as the 0's or non-conflict locations in the study area, generating a random points process.

Ideally, random points are independent and yet numerous enough to create a stable representation of the landscape that avoids model over-or under-specification. We found no general consensus in the literature or among expert practitioners on how best to select an appropriate number of random points. Most studies that use random points only indirectly address these issues. In a study by Boyce et al. (2002) evaluating resource selection functions (RSF) for grizzly bear habitat, issues of sample sizes for random points were not addressed. Another study by Perestrello de Vasconcelos et al. (2001) used a systematic random sample with a fixed distance of 11.7 km between random points in a study to predict fire ignition causes. Presumably the fixed distance among random points served to minimize correlative effects and was based on an understanding of landscape conditions. However, the authors did not provide explicit justification for their choice of the fixed distance that affects sample size.

We used a “weighted approach” to protect against model over-specification. D.J. Mattson (per. comm., September 12, 2002) has suggested using weighted logistic regression to reduce or downweight the amount of information contributed by each random point to the model degrees of freedom. In this approach, random points are weighted to reflect the sample size of observed phenomena—in this case, human-grizzly

bear conflicts. We used 2032 random points for this approach to “saturate” the 1720 km² study area. Random points were thus weighted by 0.087 (178/2032) to make their contribution to model degrees of freedom effectively equal to that of the 178 conflicts. In earlier, exploratory analysis using the weighted approach, we found that model parameters were stable with samples greater than 900 and based on previous modeling efforts using Hosmer-Lemeshow goodness-of-fit statistics, we found that a weighted approach showed no evidence of lack of fit.

Since there was no obvious direction from the literature on how best to use random points, we also compared the weighted approach to an unweighted model and a “spatial similarity” model to compare model fit and the effects that different random sample sizes had on model parameters. In the unweighted approach we treated all 2032 random points as a census and in the “spatial similarity” approach we approximated the degree of spatial proximity found in our observations (ave. distance to nearest conflict; 0.51 km) with a corresponding number of random points that roughly exhibited the same degree of spatial dispersion (ave. distance of nearest random point using 100 samples of 1000 points was 0.54 km). This was an *ad-hoc* attempt to ensure that random points would contribute roughly the same amount of spatial information to the model than would observed conflicts. We found that the unweighted model showed moderate evidence of lack of fit based on Hosmer-Lemeshow goodness-of-fit statistics and the spatial similarity model showed some evidence of lack of fit. The spatial similarity approach also relied on generating 100 samples of size 1000 and thus resulted in averages of the Hosmer-Lemeshow statistic that ranged from approximately 10 – 20. Since many of these averages could show moderate to strong evidence of lack of model fit, the spatial

similarity approach was not ideal. The spatial similarity model resulted in several additional variables being included in the model compared to the weighted model. We also found that predicted contour probability plots (discussed in further detail below) for the population and spatial similarity plots did not visually agree well with the observed conflict points. For these reasons, we have relied on a weighted model approach for all subsequent analysis.

Model Assumptions

Conflict Points

We chose not to directly address the effects of multiple conflicts involving individual bears as there was no data on the identity of bears involved with 52% (94) of the conflicts. If we had tried to directly address this issue of non-independence by factoring in the identity of bears as an explanatory variable, over half the observations would have been deleted because of missing data. Along the RMF, a steady increase in observed numbers of females with cubs has occurred over the past 16 years. Based on this estimate and our study area size, 50 grizzlies likely use the study area during a given year (M.J. Madel, personal communication, January 10, 2003.). We recognize that conflicts are likely non-independent in many cases, but we are merely trying to associate conflict locations with attractant sources. If an individual bear prefers a specific attractant source and this leads to multiple conflicts, we believe this represents the importance of this type of attractant.

Random Points

We acknowledge that there are some limitations using random points, namely choosing an appropriate number of random points to avoid over - or under - specification

of models and differences in interpretations with presence/absence (used - vs.- unused) data versus presence/availability (used - vs. - available) data (see Boyce et al., 2002). In our case, conflicts represent used locations but we could not estimate a sample of unused sites because grizzlies may use any number of locations in the study area for which we could not account. Boyce et al. (2002) suggest that in this context, the appropriate way to characterize the use of conflict data and random points is one of presence versus availability where “available” locations are based on a random sample of landscape locations. We have done this, yet the model tends to treat these data as presence/absence data by assuming that locations in the study area are equally available to bears and that grizzlies select for certain habitats when in fact not all areas are equally available and bears may use areas that did not have recorded conflicts. However, the vegetative cover type, specifically the riparian cover class, helped account for differences in availability indirectly, but not completely. Intensive monitoring and data from grizzly bear habitat use through radio telemetry or Global Positioning Systems (GPS) locations would be necessary to more fully examine the differences in presence/absence data versus presence/availability data. However, in this research we are primarily concerned with the types of attractants that are associated with conflicts and have made efforts to control for the underlying habitat conditions that contribute to the likelihood of conflict.

Landscape Features

Jonkel et al. (1979), Aune and Kasworm (1989), and Madel (1996) have found that riparian areas are an important component of grizzly bear habitat in the study area and along the RMF for grizzly bear life history and seasonal dietary needs. Madel (1996) has found that females with cubs often have overlapping home ranges on low elevation

private lands and spend extensive periods across seasons on private agricultural land (Madel, 1996). Riparian areas within the Teton River watershed as well as farther north, support some of the highest bear densities during spring and fall along the RMF (M.J. Madel, per. comm. February 10, 2003). We acknowledge that riparian vegetation may play a more important seasonal role in grizzly bear food requirements particularly in the spring and fall, but we also felt that it was an important habitat component for movement, security cover, and foraging opportunities in the summer as well (M.J. Madel, per. comm. February 10, 2003). Hence we included it in our model selection analysis as a “year-round” variable.

Agricultural Attractants

We classified both “managed” and “unmanaged” bone yards as year-round variables. We expected that locations of managed bone yards were less of an attractant to grizzlies particularly in the spring (i.e., there should be little or no carrion available) than unmanaged bone yards. However, we chose to treat managed bone yards conservatively since based on our interview data, livestock related land users indicated that they might occasionally use their managed bone yards for disposal of animals during the summer or fall. It is also possible that since managed bone yards were included in the MFWP redistribution program at different times, bears may still investigate a bone yard that had once been a repository of animal protein for many years despite having changed management status.

Based on our interviews with the resident beekeeper for the study area, all beehive sites were occupied by honeybees by late May and stayed occupied through mid-October. Despite the short window of time that beehives were available to grizzly bear during the

spring season, we chose to include both fenced and unfenced beehives as year-round variables since there were beehive-related conflicts that occurred in the spring season.

Based on our interviews and mapping sessions with livestock related land users and discussions with the Teton County Extension Agent, we found that cattle and sheep pasture locations had generally been used for seasonal or time-controlled grazing over the 16-year study time frame (D. Clark, per. comm. May 19, 2003). While resting and rotating pastures certainly occurs, we asked livestock related land users to identify the general pasture locations that they traditionally used for spring, summer, and fall pastures during 1986-2001. The seasons of pasture use fit well with our seasonal definitions. Ideally, we would have preferred a year-by-year account of where livestock were pastured for the study time frame. However, this would have placed an excessive time burden on livestock related land users to reproduce such information. We felt that livestock related land users' knowledge of their operations and the general locations they told us they use for their spring, summer, and fall pasture locations was sufficient for our analysis. We made the assumption that pasture locations were generally stable despite site-specific changes in livestock pasture locations that might occur due to changes in forage quality, periodic drought, or changes in herd size, etc. The Teton County Extension Agent also indicated that cattle calving areas, spring cattle pastures for cow/calf pairs, lambing areas, and spring sheep pastures for ewe/lamb pairs were the most spatially stable pasture locations since these were located in close proximity to the ranching facilities in order for producers to oversee the calving and lambing process during the spring. The extension agent also suggested that these same pastures often are replanted with different grass species due to consistent annual use (D. Clark, per. comm.

May 19, 2003). We also accounted for situations where livestock producers may have only had summer or fall pastures in the study area and calved elsewhere or where producers calved and had spring pastures within the study area but had summer grazing leases outside the study area. This way, seasonal livestock pasture locations were only available during their specific season of use as explained to us by the livestock producers. We accounted for changes in land ownership and lease status by contacting and interviewing all previous owners or lessees and documented their pasture locations and bone yard management. We did not include pastures that livestock related land users had in the Conservation Reserve Program (CRP). While these are typically taken out of production for 10-year intervals, during drought emergencies, they can be released for periodic grazing with approval from the National Resource Conservation Service. This occurs very infrequently and few landowners in the study area had land in CRP. We did not feel that this omission had any measurable impact on our model analysis.

Model Selection

We used Akaike's Information Criterion (AIC) and Hosmer-Lemeshow goodness-of-fit statistics to produce a spring, summer, and fall model and an annual model. For the three seasonal models, we relied on AIC_C to account for smaller sample sizes (Burnham and Anderson, 1998). AIC is a common model selection technique used to compare a series of plausible models to one another. AIC values are adjusted when additional variables are added to a particular model. By minimizing AIC values in comparison to other models, a final fitted model can ideally result in one that accounts for the most variation with the fewest number of variables. We based our model selection on the variables found in Table 7.1 along with an understanding of the built-in correlations

between variables and produced the four final models based on minimizing AIC values and those with no evidence of lack of model fit based on Hosmer-Lemeshow goodness-of-fit statistics. We also accounted for possible interactions among all variables in Table 7.1.

During the model selection process we found that three pairs of variables: distance to nearest spring, summer, and fall sheep and cattle pastures were highly collinear. Sheep and cattle pastures are located very close to one another throughout the study area. This is not surprising since sheep are typically a smaller component of larger cow/calf ranching operations along the RMF and are often grazed in close proximity to cattle. There were only 9 operators over the 16-year period who raised sheep along with their main cow/calf operations. It became apparent during the model selection process that these variables were essentially providing the same information. In order to simplify the model selection process, we combined these variables to be the “minimum distance to the nearest spring sheep or cattle pasture,” “minimum distance to the nearest summer sheep or cattle pasture,” and “minimum distance to the nearest fall sheep or cattle pasture” (Table 7.1). Separately, spring, summer, and fall sheep and cattle pastures were included in all models we fit suggesting that we could not separate out the effects of these variables. By combining the distance measures one does lose the ability to distinguish between sheep and cattle, but we found that the effect of these variables in the model was not one or the other, but either.

In extensive prior analysis, we eliminated variables that were not relevant for possible inclusion in the model selection process described above. These variables were in some cases collinear with other variables or did not add any insight to understanding

conflict likelihood. We justified reducing the total number of variables prior to model selection to only those that were plausible since AIC techniques require extensive and iterative comparisons of multiple models with different numbers of variables in different combinations. See Appendix A for a further discussion of those variables eliminated in the earliest stages of our modeling efforts.

Contour Probability Plots

We used the inverse logit transformation on each model to create a contour probability plot to evaluate the predictive capacity of each model. We also produced the contour plots to locate areas where conflicts were predicted but where few if any occurred. This will facilitate further analysis to study less tangible factors that are important to understanding conflicts like rancher attitudes towards bears, animal husbandry practices that may minimize conflicts, or the possibility that conflicts were occurring but not being reported in these areas.

The actual inverse logit transformation of each model resulted in a data matrix where all reported conflicts and random points took on a probability value based on the model coefficients from the spring, summer, fall, and the annual model. These data were then visually displayed using probability contours with isopleths or contours $>.50$ and a $.10$ contour interval. We displayed each contour probability plot with seasonal conflicts and conflict hotspot density maps for spring, summer, and fall from previous analysis in Chapter 6. (see Figures 6.3, 6.5, 6.7; pg. 101 - 108). We also displayed the contour plot from the annual model with all conflicts ($n=178$) and a corresponding density surface map from previous analysis in Chapter 6 (see Figure 6.10; pg. 115).

Contours represent the predicted probability of conflicts versus random points occurring for each model. Model outputs can be interpolated through contour mapping in that any areas without contours (i.e. < 0.50) are areas where random points are more likely to occur than conflict points, and vice-versa. Like a weather map that predicts cooler to warmer temperatures, contours represent the increased probability that a conflict will occur as one moves from .50 to .90. Contours also illustrate that spatial context of possible conflict patterns. For example, as contours tighten in concentric rings with corresponding increases in probabilities, a well-fitted model would visually agree with a pattern of clustered conflicts. In other words, the contours .50 - .90 represent a predicted gradient where conflicts are more likely to occur.

Attributing Variables

We used GIS to attribute or ascribe continuous and categorical measures to all variables. As discussed previously, we only attributed seasonal variables based on what agricultural attractants were available during the spring, summer, and fall. All distance measurements were made to the nearest 100 meters and converted to kilometers to facilitate statistical interpretations of model coefficients. Distance measurements were made to the middle or centroid of all livestock pastures. All presence / absence variables were attributed using a moving window routine in GIS where a 50-meter grid was placed over the study area boundary and at each grid cell, a 1.6 km search radius passed around that cell and assigned a presence/absence (1 or 0) value to a conflict or random point that might be located on that particular grid cell. In other words, conflicts and random points overlaid the grid cells and the 1.6 search radius was run for every grid cell in the study area. For example, if an unmanaged bone yard was within the search radius, that conflict

or random point was given a 1. If there was not an unmanaged bone yard, then the point was assigned a 0.

We chose a search radius of 1.6 km based on the recommendation of researchers from southern Alberta (Gibeau 2000; Gibeau et al. 2002). These researchers found daily movement distances based on 4 years (across seasons) of intensive radio telemetry work on female grizzly bears (n=17) using 385 daily movement distances. We used the average distance moved by female grizzly bears with cubs over a 24-hour period, taking the mean of when people were active (1.3 km; 08:00-17:00) versus inactive (1.9 km; 17:00-08:00) as an estimate of daily movement. There were no daily movement data for grizzly bears on the Rocky Mountain Front, so we used data from the most similar ecosystem available to derive a biologically meaningful search radius. Conditions that affect the probability of conflict likely operate at several scales, including the lifetimes, years, and seasons for individual bears and Mattson has suggested that features encountered by bears during 24-hr to 48-hr foraging bouts may have the greatest influence on likelihood of conflict. In Yellowstone National Park this is roughly 9 km² (Schleyer et al. 1984, Haroldson & Mattson, 1985). A 1.6 km search radius results in an 8 km² circular area and is consistent with the Yellowstone information.

RESULTS

Seasonal Models

Spring Model

Percent riparian cover type and calving areas had strong effects on probability of human-grizzly bear conflicts in the spring (Table 7.2). A 10% (.1 unit) increase of riparian cover type increased the odds of conflict by 1.88 times (95% CI: (1.367, 2.591)).

If the unit increase was 20%, the odds of conflict increased by 3.54 times ($.20 \times 6.3258 = 1.2651$ and $e^{1.2651} = 3.543$). In terms of area, a 1.6 km search radius is approximately 8.04 km^2 (3.1 mi^2) or 804 hectares (1,984 acres). For practical comparison, an increase of 20% in riparian vegetation is equivalent to an increase of approximately 161 hectares (397 acres). The odds of a conflict occurring inside calving areas were more than 3 times greater than not being inside calving areas (95% CI: (0.931, 12.099)). However, the standard error for this variable was large, so the odds were not significantly different from 1.

The minimum distance to a spring sheep or cattle pasture had a modest effect on the likelihood of conflict but had smaller standard errors. For every 1 km increase in distance moved away from either a sheep or cattle spring pasture, the odds of conflict decreased by 1.47 times (95% CI: (1.126, 1.926)). Lambing areas had a similar effect on the odds of conflict. For every 1 km increase in distance moved away from this attractant, the odds of conflict decreased by 1.075 times (95% CI: (1.020, 1.136)). If the odds are >1 , then the parameter has an impact on conflict likelihood. There was no evidence of lack of fit based on the Hosmer-Lemeshow goodness-of-fit statistic (Table 7.2).

Table 7.2. Results of the spring weighted logistic model explaining the observed distribution ($n=93$) of human-grizzly bear conflicts along the Rocky Mountain Front, 1986-2001 compared to a distribution of 1057 random points.

Variable	Parameter Estimate	Standard Error	Exp(B)	95% C.I. for Exp (B)	
				Lower	Upper
Percent Riparian Cover ¹ Type in 1.6 km search radius	0.6325	0.1632	1.8823	1.367	2.591
Min. distance to nearest sprg. sheep or cattle pasture ²	- 0.3872	0.1370	0.6789	0.519	0.888
Distance to sheep lambing area	- 0.0731	0.0275	0.9295	0.880	0.980
In/Out cattle calving area	1.2119	0.6542	3.3568	0.931	12.099
Constant	0.1940	0.6079	1.2140		
Hosmer-Lemeshow GOF	10.8501	p-value =0.2103			

¹ Parameter estimate reflects a 10% (.10 unit) increase for coefficient, standard error, and confidence interval calculations. The original values for "Percent Riparian Cover Type" were: parameter estimate=6.325, standard error=1.632. We multiplied the original parameter estimate and standard error by .10 to arrive at the result in the table above. This was done to facilitate interpretations regarding a meaningful increase in the percentage of riparian vegetation within a 1.6 km search radius.

² When parameters estimates are negative, 1/Exp(B) provides the actual odds for interpretation. We left the original exponentiated parameter estimates in all tables but provided the interpretable odds in the results and discussion sections throughout.

Spring Model Contour Probability Plot

The spring contour probability plot showed fairly good predictive capacity. There was general overlap with a majority of the spring conflicts and conflict hotspots, particularly hotspots C, D, and E. However, there were noticeable areas in the northeast and northwest sections of the study area without conflicts despite model predictions. There were discrepancies between model predictions and actual conflict locations to the north of Hotspot D and in southwest central portions of the study area (Figure 7.2). These discrepancies exist in large part because the spring model does not include non-seasonal attractants such as unmanaged bone yard or unfenced beehives, due to a lack of available degrees of freedom. This reduces the predictive capacity of the model.

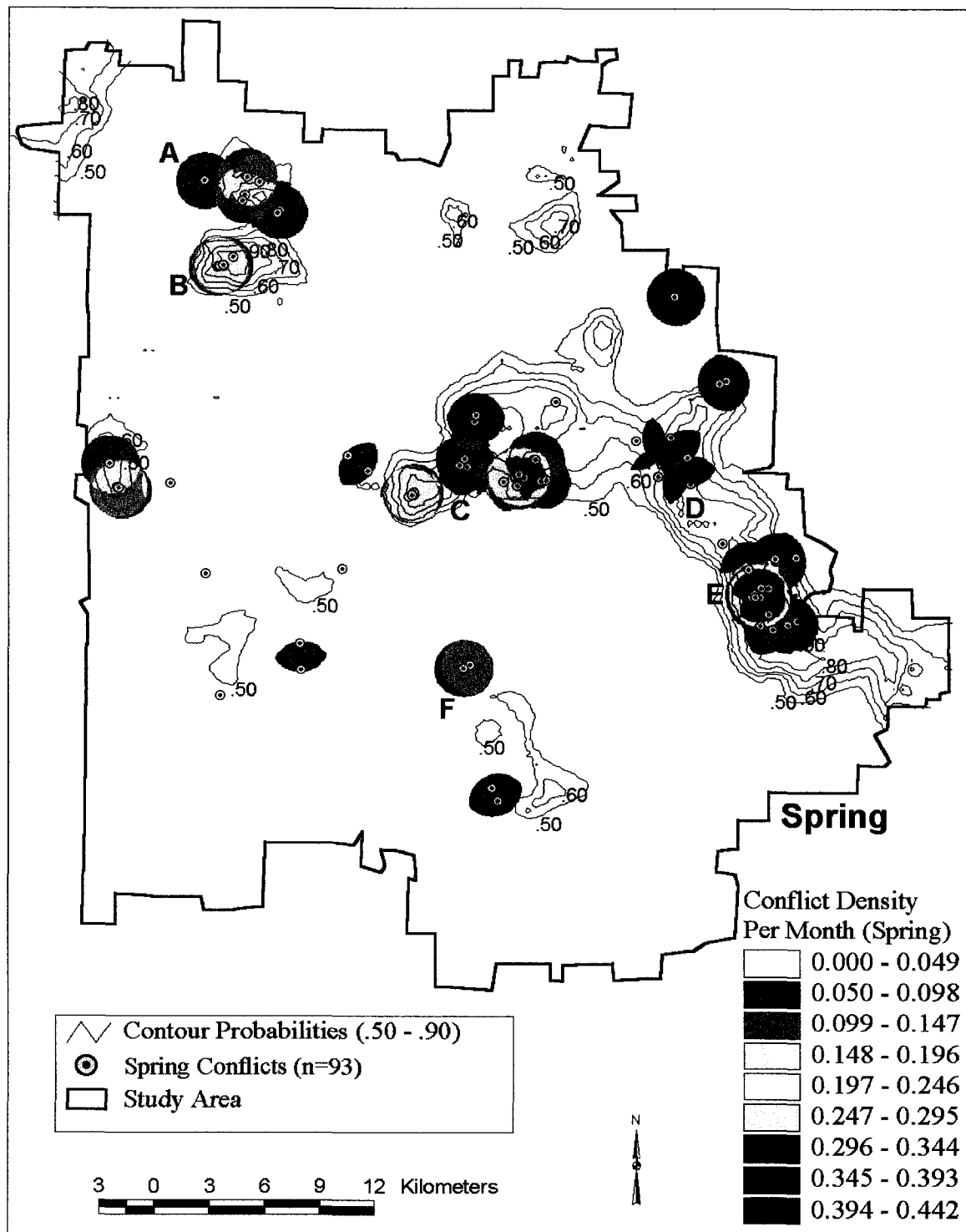


Figure 7.2. Spring model contour probability plot with spring conflict densities for hotspots A-F (n/km²/month; n=93).

Summer Model

As expected, riparian vegetation was also associated with conflicts in the summer model (Table 7.3.). A 10% (.1 unit) increase of riparian cover type increased the odds of conflict by about one and a half times (95% CI: (1.011, 2.145)); slightly less than in the spring model. The distances to sheep or cattle pastures were also associated with summer conflicts. For every 1 km increase in distance moved away from these attractants, the odds of conflict decreased by 1.657 times (95% CI: (1.011, 5.434)). The presence of unfenced beehives had a large standard error and did not significantly contribute to an increased likelihood of conflict ((95% CI: (0.902, 3.279)). The summer model showed strong predictive capacity since there was clearly no evidence of lack of fit based on the Hosmer-Lemeshow goodness-of-fit statistic.

Table 7.3. Results of the summer weighted logistic model explaining the observed distribution ($n=50$) of human-grizzly bear conflicts along the Rocky Mountain Front, 1986-2001, compared to 569 random points.

<i>Variable</i>	<i>Parameter Estimate</i>	<i>Standard Error</i>	<i>Exp(B)</i>	<i>95% C.I. for Exp (B)</i>	
				<i>Lower</i>	<i>Upper</i>
Percent Riparian Cover ¹ Type in 1.6 km search radius	0.3876	0.1917	1.4734	1.011	2.145
Min. distance to nearest sum. sheep or cattle pasture	- 0.5052	0.1621	0.6033	0.184	1.968
Unfenced beehive present	1.0845	0.6059	2.957	0.902	9.699
Constant	0.4545	0.5737	1.575		
<i>Hosmer-Lemeshow GOF</i>	2.8129	p-value =0.9455			

¹ Parameter estimate reflects a 10% (.10 unit) increase for coefficient, standard error, and confidence interval calculations. The original values for "Percent Riparian Cover Type" were: parameter estimate=3.8769, standard error=1.9179. We multiplied the parameter estimate and standard error by .10 in the table above. This was done to facilitate interpretations regarding a meaningful increase in the percentage of riparian vegetation within a 1.6 km search radius.

Summer Model Contour Probability Plot

The summer model probability plot showed fair predictive capacity. While a majority of the summer conflicts were encompassed by the predicted contours of the model, there were several areas in the north-central and northeast portions of the study area where the summer model predicted conflicts but where none occurred. The southwest corner of the study area also did not fit with model predictions. Again, a lack of available degrees of freedom in the summer model may be reducing the model's predictive capacity. With the exceptions of Hotspots H, L, and N, the remaining hotspots were generally well matched with the model predictions.

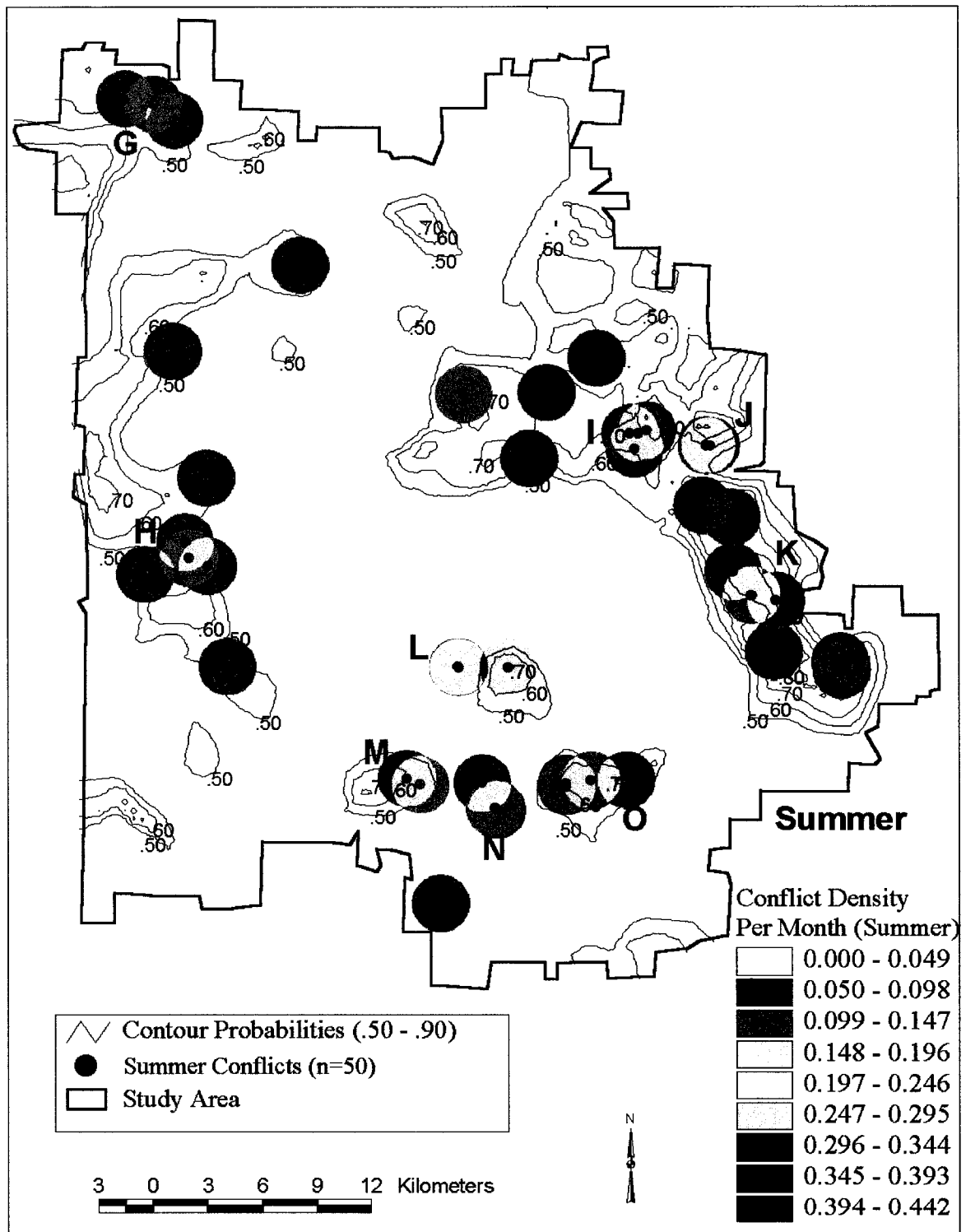


Figure 7.3. Summer model contour probability plot with summer conflict densities for hotspots G-O ($n/\text{km}^2/\text{month}$; $n=50$).

Fall Model

Riparian vegetation was a dominant variable in the fall model, even more so than in the other seasonal models. A 10% (.1 unit) increase of riparian cover type increased the odds of a fall conflict by more than two and a half times (95% CI: (1.474, 4.584)). The minimum distance to either a fall sheep or cattle pasture also was a factor influencing fall conflicts. A 1 km increase in distance from either a sheep or cattle pasture, decreased the odds of conflict by 1.501 times (95% CI: (1.029, 2.188)) and a 1 km increase in distance away from a managed bone yard slightly decreased the odds of fall conflict by 1.090 times (95% CI: (1.087, 1.105)). There was no evidence of lack of fit based on the Hosmer-Lemeshow goodness-of-fit statistic.

Table 7.4. Results of the fall weighted logistic model explaining the observed distribution ($n = 35$) of human-grizzly bear conflicts along the Rocky Mountain Front, 1986-2001, compared to a distribution of 406 random points.

<i>Variable</i>	<i>Parameter Estimate</i>	<i>Standard Error</i>	<i>Exp(B)</i>	<i>95% C.I. for Exp (B)</i>	
				<i>Lower</i>	<i>Upper</i>
Percent Riparian Cover ¹ Type in 1.6 km search radius	0.9554	0.2894	2.599	1.474	4.584
Min. distance to nearest fall ² sheep or cattle pasture	- 0.4051	0.1919	0.666	0.457	0.971
Distance to nearest managed bone yard	- 0.0856	0.0417	0.917	0.845	0.996
Constant	0.0000	0.7997			
<i>Hosmer-Lemeshow GOF</i>	4.6391	p-value =0.7953			

¹ Parameter estimate reflects a 10% (.10 unit) increase for coefficient, standard error, and confidence interval calculations. The original values for "Percent Riparian Cover Type" were: parameter estimate=9.5541, standard error=2.8946. We multiplied the parameter estimate and standard error by .10 in the table above. This was done to facilitate interpretations regarding a meaningful increase in the percentage of riparian vegetation within a 1.6 km search radius.

² When parameters estimates are negative, 1/Exp(B) provides the actual odds for interpretation. We left the original exponentiated parameter estimates in all tables but provided the interpretable odds in the results and discussion sections throughout.

Fall Model Contour Probability Plot

The fall model predictions fit well with the actual distribution of conflicts. Nearly all conflicts were within or adjacent to contours where the probability of conflict was $>.50$. Hotspots Q and R overlapped well with model predictions but portions of Hotspots P and S showed less overlap. There were some isolated locations where the model predicted conflicts but none occurred, particularly southwest of Hotspot P and northeast of Hotspot S. Like the spring and summer models, lack of available degrees of freedom may be diminishing this model's predictive capacity.

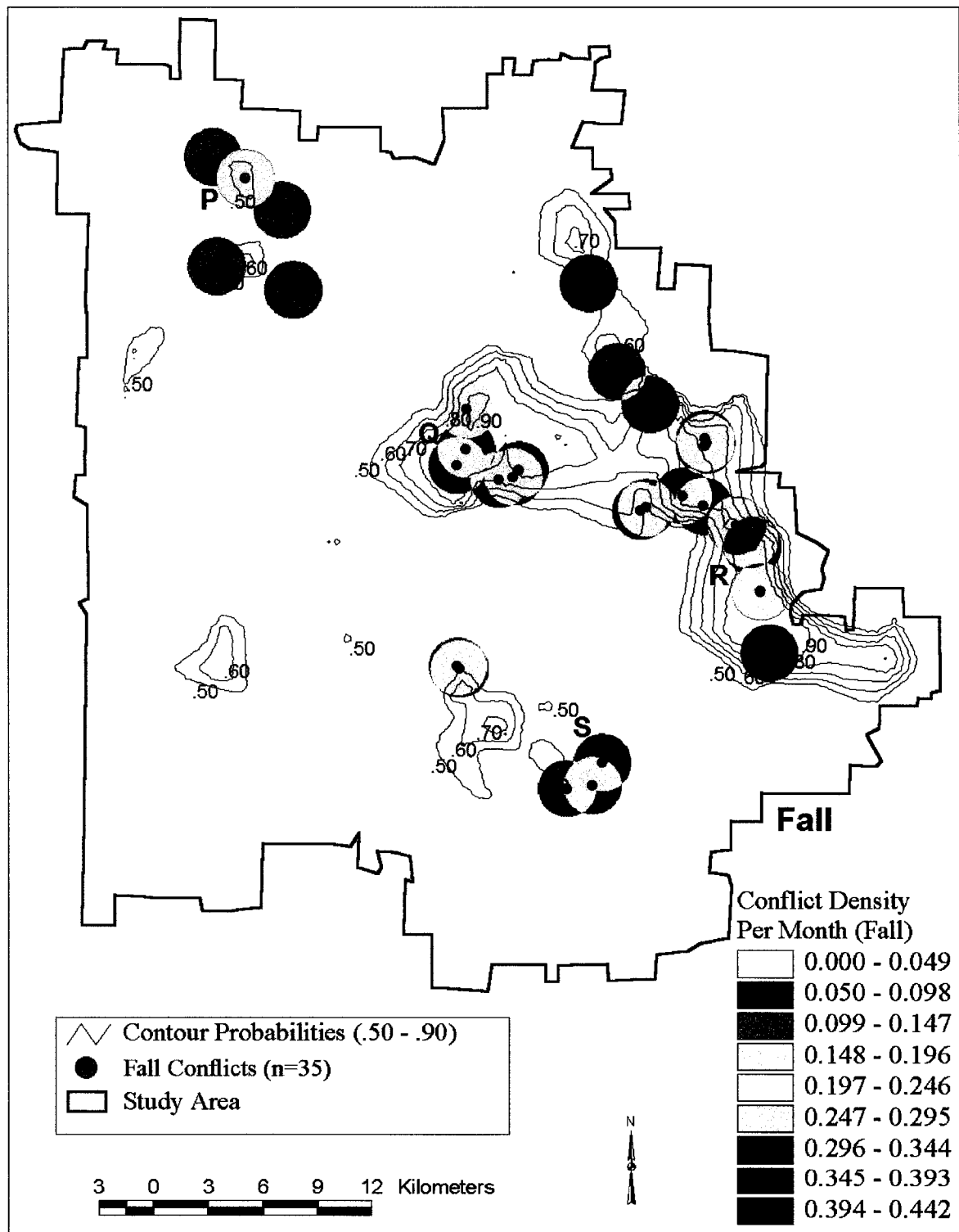


Figure 7.4. Fall model contour probability plot with fall conflict densities for hotspots P-S ($n/\text{km}^2/\text{month}$; $n=35$).

The Annual Model

Since the annual model accounted for seasonal and year-round variables to predict overall or annual conflict, it was not unexpected that nearly all variables from the spring, summer, and fall models were found in the full annual model. There was one exception where the variable “distance to managed bone yard” did not show up in the annual model. Nevertheless, all seasonal variables that were unique to the spring, summer, and fall models were found in the annual model and parameter estimates did not differ appreciably. Since the annual model relied on a larger sample ($n=178$), there were more observations available for improved parameter estimation. Subsequently, there were three new variables that were included in the annual model that all increased the likelihood of conflict. These were: 1) the presence of unmanaged bone yards, 2) the presence of fenced beehives, and 3) an interaction term, “unfenced beehives x unmanaged bone yards” (Table 7.5).

The presence of unmanaged bone yards increased the odds of conflict by 2.321 times (95% CI: (1.165, 4.624)). Additionally, the presence of fenced beehives had an effect on conflict occurrence. The presence of this variable within a 1.6 km search radius increased the odds of conflict by more than 5 times (95% CI: (1.651, 16.474)). The third additional variable was the interaction term. The presence of both unfenced beehives and unmanaged bone yards within a 1.6 km search radius increased the odds of conflict by 0.177 times. (95% CI: (.030, 1.021)). However, this variable had a relatively large standard error and should be interpreted with care. Additionally, the probability of conflict is dampened with these variables in the presence of each other.

Percent riparian cover type within a 1.6 km search radius and the minimum distance to the nearest spring, summer, and fall sheep or cattle pasture all contributed to the likelihood of annual conflict. The minimum distances to spring, summer, fall cattle or sheep pastures increased the odds of conflict by 1.461, 1.590, and 1.640 times respectively (95% CIs: (1.166, 1.831); (1.251, 2.024); (1.270, 2.136)). The presence of the year-round variable, unfenced beehive, had a smaller standard error in the annual model compared to the spring model (due to increased precision) and increased the odds of conflict by 3.320 times (95% CI: (1.355, 8.129)). For every 1 km increase in distance moved away from a sheep lambing area, the odds of conflict decreased by 1.064 times (95% CI: 1.047, 1.117). Being inside a calving area increased the odds of conflict 2.655 times (95% CI: .760, 9.272) but this result is not significant due to the large standard error (Table 7.5). There was no evidence of lack of fit for the annual model based on the Hosmer-Lemeshow goodness-of-fit statistic (Table 7.5).

In the following example, we provide an illustration of how the actual probability of conflict changes for a given set of x-values based on specified location (UTM 398932, 5317674) in the study area. Using the annual logistic regression model we calculated the probability of conflict with and without the presence of an unfenced beehive for this location. Without the presence of an unfenced beehive in the 1.6 km search radius the probability of conflict was .26. With the presence of an unfenced beehive in the 1.6 km search radius, the probability of conflict increases to .54.

Table. 7.5. Results of the annual weighted logistic regression model explaining the observed distribution (n =178) of human-grizzly bear conflicts along the Rocky Mountain Front, 1986-2001, compared to a distribution of 2032 random points.

<i>Variable</i>	<i>Parameter Estimate</i>	<i>Standard Error</i>	<i>Exp(B)</i>	<i>95% C.I. for Exp (B)</i>	
				<i>Lower</i>	<i>Upper</i>
Percent Riparian Cover ¹ Type in 1.6 km search radius	0.5766	0.1154	1.779	1.419	2.231
Min. distance to nearest sprg. ² sheep or cattle pasture	- 0.3789	0.1147	0.684	0.546	0.857
Min. distance to nearest summ. sheep or cattle pasture	- 0.4639	0.1223	0.628	0.494	0.799
Min. distance to nearest fall sheep or cattle pasture	- 0.4987	0.1327	0.607	0.468	0.787
Unmanaged bone yard present	0.8421	0.3517	2.321	1.165	4.624
Unfenced beehive present	1.2000	0.4569	3.320	1.355	8.129
Fenced beehive present	1.6519	0.5867	5.216	1.651	16.474
Distance to nearest lambing area	- 0.0624	0.0245	0.939	0.895	0.955
In/out of cattle calving area	0.9766	0.6380	2.655	0.760	9.272
Unfenced beehive x unmanaged bone yard ³	- 1.7268	0.8918	0.177	0.030	1.021
Constant	- 0.2079	0.3968	0.812		
<i>Hosmer-Lemeshow GOF</i>	8.2740	<i>p-value =0.4071</i>			

¹ Parameter estimate reflects a 10% (.10 unit) increase for coefficient, standard error, and confidence interval calculations. The original values for "Percent Riparian Cover Type" were: parameter estimate=5.766, standard error=1.1154. We multiplied the parameter estimate and standard error by .10 in the table above. This was done to facilitate interpretations regarding a meaningful increase in the percentage of riparian vegetation within a 1.6 km search radius.

² When parameters estimates are negative, 1/Exp(B) provides the actual odds for interpretation. We left the original exponentiated parameter estimates in all tables but provided the interpretable odds in the results and discussion sections throughout.

³ Note: The negative sign for the interaction term, unfenced beehive x unmanaged bone yard, illustrates that the interaction is negative, not that the odds of conflict decrease in the presence of both. The odds of conflict increased 0.177 times when both were present within a 1.6 km search radius.

The negative interaction means that when one variable is in the presence of the other, there is a dampening effect where the increase in probability when the terms are combined is less than the sum of their probabilities combined. In a hypothetical example, if the probability associated with one term is .30 and the probability associated with the other term is .15, a negative interaction would result when the increase might be only .35, a value less than their sum (.45). In this same hypothetical example, a positive interaction would occur when their combined effect on the probability of an event might be .80.

Annual Model Contour Probability Plot

The contour probability plot of the inverse logit transformation of the annual model indicates a fairly strong overlap with all conflicts during 1986-2001. The density surface map (non-normalized) based on all conflicts generally fits within predicted contours $>.50$. However, there were locations in the northeast and northwest portions of the study area where few conflicts occurred despite model predictions with contour intervals ranging from $.50 - .80$. There were also several isolated conflicts in the west-central half of the study area where model predictions were below $.50$.

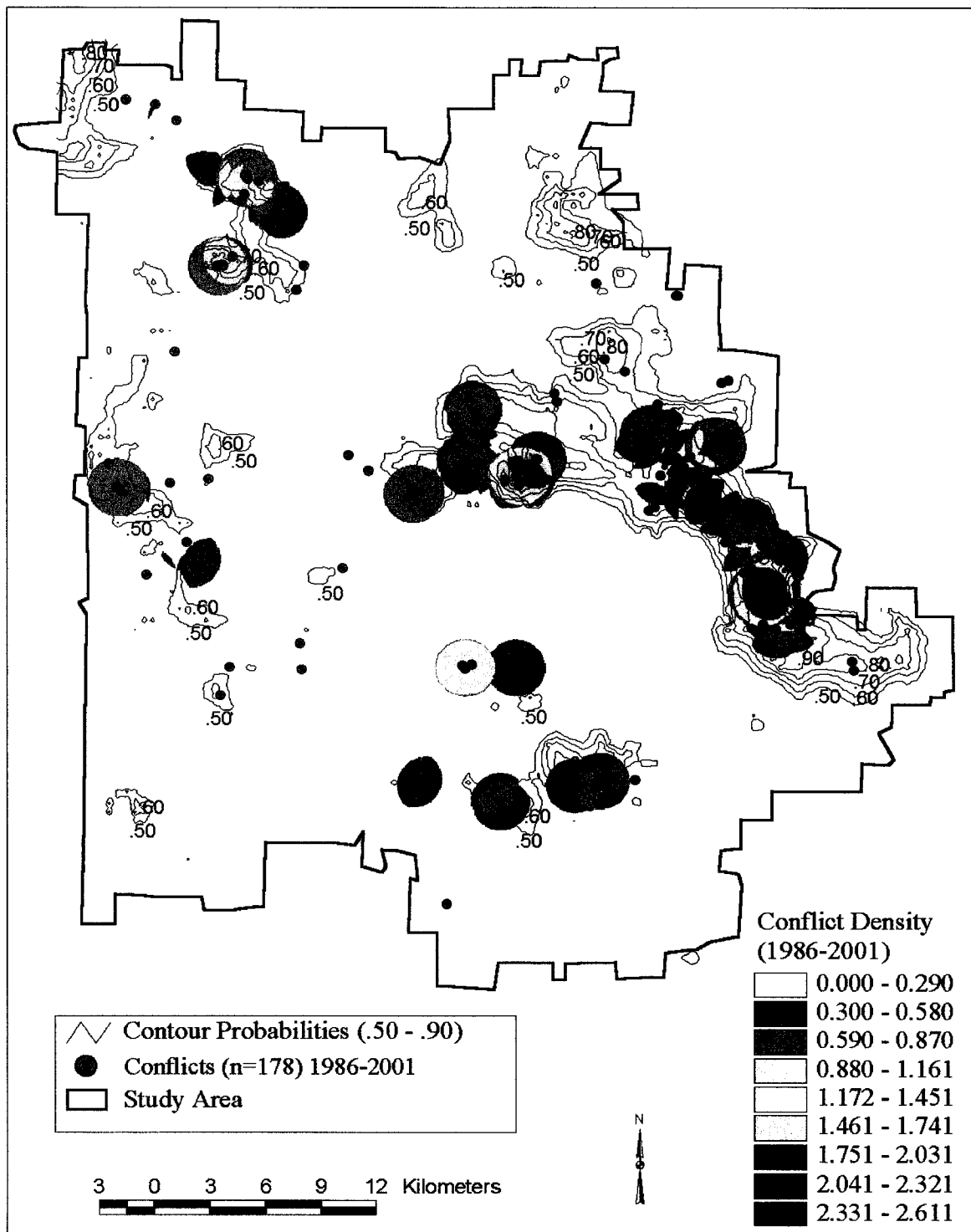


Figure 7.5. Annual model contour probability plot with conflict densities for 1986-2001, (n/km^2 ; $n=178$).

DISCUSSION

General Overview

After controlling for the strong influence of riparian vegetation, it was clear that a collection of seasonally available and year-round attractants had an effect on the likelihood of conflicts on private agricultural lands. This confirmed the relative importance of attractants in affecting the odds of conflict and suggests that conflict occurrence was not just a result of being located in proximity to productive bear habitat. We found during the model selection process that the attractants we identified in the seasonal and annual models were *all important after accounting for the dominating effect of riparian cover type*. With the addition of riparian cover type during model selection, these attractants still contributed strongly to the likelihood of conflict, confirming their importance above and beyond being in a riparian area. Additionally, we accounted for changes in types, spatial locations, and management status of attractants over the 16-year study time frame and still found a *consistent set of attractants* that contributed to conflicts. For example, we did not know if there would be measurable differences in bone yards that were managed versus those that were unmanaged, but we wanted to record if and when each bone yard in the study area went from an unmanaged to a managed state. Recall that managed bone yards in the study area were part of the MFWP carcass redistribution program where participating ranchers had their dead livestock picked up from their bone yards in early spring. We expected that managed bone yards would be less of an attractant, but we knew from our interviews that some ranchers may have occasionally used their managed bone yard throughout a year. By accounting for these types of changes over time, we were also able to establish the relative contribution

that different types of management actions like bone yard management have on the likelihood of conflicts. In this case, unmanaged bone yards were clearly an important attractant whereas managed bone yards were not. Other types of changes we accounted for were the types of livestock that producers may have raised (cattle vs. sheep) and the development and protection status of beehives. We discuss these attractants in more detail below.

The seasonally available attractants in the spring model were the minimum distance to a sheep or cattle pasture, distance to sheep lambing areas, and the presence of calving areas. The summer model illustrated that seasonally available sheep or cattle pastures had effects on the odds of conflict and the year-round attractant, presence of unfenced beehives, was another important factor contributing to summer conflicts. Both fall sheep and cattle pastures were important attractants that were associated with conflicts in the fall model. All of the attractants mentioned above were found in the annual model as well. Moreover, the annual model had an additional variable, the presence of unmanaged bone yards. The important point here is that the annual model accounted for seasonality and was able to provide better parameters estimates and additional information about attractants associated with conflicts due to a larger sample size. At this point it is important to illustrate the link between the seasonal and year-round attractants that we found in our logistic regression model results with our previous work on conflict hotspots with an emphasis on spatial patterns of both attractants and conflicts. Thus, we need to briefly discuss how conflict hotspots are important to the model results.

Our previous analysis of conflict hotspots provided evidence that a majority of conflicts (75%) during 1986-2001 occurred in discrete spatial locations in the study area or what we defined as seasonal conflict hotspots. Seasonal conflict hotspots accounted for approximately 8% of the study area. More importantly, we found that seasonal and year-round attractants were found in close proximity to one another within hotspots and were generally located along river and creek bottoms and contained varying amounts riparian vegetative cover types. It was also evident that specific seasonal hotspots had spatial overlap from some seasons to the next (see Chapter 6 pg. 116). We found that 62% of all conflicts were found in hotspots with spatial overlap and that these overlapping hotspots all contained beehives and bone yards (year-round attractants). It is likely that regular availability of seasonal attractants found in close proximity to one another in the overlapping hotspots in addition to the background or year-round beehives and bone yards, are *key ingredients* for hotspot formation. Moreover, the annual model results suggest that separately, unmanaged beehives and unmanaged bone yards were strongly associated with an increased likelihood of conflict, although the effect is dampened in the presence of both.

Although we knew that some conflicts were associated with beehives and livestock depredations, we have been interested in explaining *spatial patterns of conflict, not causes of conflict*. Our analysis provides evidence that specific contexts in the study area that have the year-round attractants, unmanaged bone yards and unfenced beehives, in addition to seasonally available attractants help explain the strong patterns of conflict hotspots we observed in the study area. This would also help explain in part, why there were places in the study area that had some features and attractants that one might expect

to lead to conflict, but few if any conflicts. For example, it was evident that many locations in the study area had calving areas and spring cattle pastures in riparian areas i.e., bear habitat and livestock, but few if any conflicts. According to our analysis, it is likely that locations such as these did not have the *collection and spatial configuration of year-round attractants and seasonally available livestock pasture arrangements* that led to the distinct patterns that we observed in overlapping hotspots. Overlapping hotspots can be thought of as problematic contexts within the landscape where there happens to be a concentration of attractants that lead grizzly bears into conflict situations. Nearly all overlapping hotspots contained beehives, bone yards, and spring, summer, and fall cattle and sheep pastures plus calving areas and lambing areas. This collection and concentration of attractants located near one another appear to be the *necessary ingredients* that help explain where a majority (75%) of conflicts occurred during 1986-2001.

Contour Probability Plots

Contour probability plots that we developed for each model provide additional insight for prediction and understanding the scale at which conflicts occur and can direct further inquiry in a spatially explicit fashion to locations in the study area where conflicts were predicted but did not occur. We found that in general, the contour probability plots developed for each seasonal model and the annual model did a fairly good job predicting the locations where conflicts would occur more often than by chance alone as supported by the Hosmer-Lemeshow goodness-of-fit statistics. These plots have relevance for directing management efforts to spatially explicit locations in the study area. This was particularly evident in the northeast section of the study area where contour plots from

the spring, summer, and annual models predicted conflicts but there were none. One plausible explanation is that conflicts were in fact occurring in these locales during 1986-2001, but livestock producers may not have reported them to wildlife managers for reasons that may be related to attitudes towards grizzly bears, distrust of state wildlife managers, or other less tangible explanations related to interests in privacy, private property rights, etc. Differences in animal husbandry practices such as intensity of herd monitoring or minimizing yearly death loss that results in less carrion being available on bone yards could be other explanations why producers in these areas, compared to others, may be having few if any conflicts. Contour plots based on models may provide meaningful insights to guide further analysis to seek “residual” explanations that cannot be solely explained through modeling efforts.

We next turn to the specific variables found in the models and discuss in greater detail their relative contribution in affecting the likelihood of conflicts.

Landscape Features

Riparian Vegetation

The presence of riparian vegetation within a 1.6 km search strongly affected occurrence of conflicts. This is not surprising. Grizzly bears in the study area are known to make extensive use of riparian and other wetland associated vegetation for security cover, seasonal forage, and movement (Aune and Kasworm, 1989). However, it is worth noting that other types of landscape features we originally included in model building did not contribute additional information to our analysis (see Appendix A). Riparian cover types were clearly more important than agricultural, forest, shrub lands, or upland

grassland cover types. Riparian cover was also a more useful measure for understanding conflicts than distance of conflict to rivers or creeks (see Appendix A).

On the Teton-Birch Creek Bear Management Unit, located within the study area, approximately 80% of grizzly bear spring habitat consists of gently sloping private lands containing fens and riparian plant communities. “Low-land bears” moved from their dens to low elevation habitats in riparian areas and remained there until the pre-denning periods (Aune and Kasworm, 1989). Females with cubs often have overlapping home ranges on low elevation private lands and spend extensive periods of each year on private agricultural lands (Madel, 1996). Riparian areas within the Teton River watershed as well as farther north, support some of the highest bear densities during the spring and fall found anywhere along the Rocky Mountain Front (M.J. Madel, per. comm. February 10, 2003). Given the amount of available attractants within or near riparian areas, conflicts between humans and grizzly bears near streams or rivers on private agricultural lands would be expected. Our model analysis indicated that riparian cover types were a vital part of understanding conflicts. However, after accounting for this strong effect, we found that a collection of agricultural related attractants contributed to the likelihood of conflicts as well.

Attractants

Seasonal Sheep and Cattle Pastures

We found the minimum distance measures to spring, summer, and fall sheep and cattle pastures were important seasonal variables that influenced conflicts. In all cases, the further in distance one moved from these seasonal pastures, the odds of conflict decreased. In many respects, this is not surprising since more than a third of all conflicts

were confirmed livestock depredations and these types of incidents occurred seasonally. However, we found it important to know that of all the livestock related landusers in the study, only 10 had raised sheep periodically during the 16-year study time frame and only four producers consistently raised sheep during 1986-2001. After accounting for this temporal change in livestock use, it was important to know that even if sheep are raised only briefly in grizzly bear habitat, that this attractant can clearly increase the odds of conflict. Perhaps most importantly, both cattle and sheep pastures were contributors to the likelihood of conflict above and beyond the effects of riparian vegetation.

Unmanaged Bone yards

Unmanaged bone yards are locations on ranches where dead livestock have been repeatedly disposed of, often for many years and, as such, are unsecured year-round attractants available to scavengers such as grizzly bears. Previous work has demonstrated that ungulate and ungulate carrion are an important dietary component for grizzly bears particularly during spring when ungulate mortality peaks (Craighead et al., 1995; Mattson, 1997; Green et al., 1997). Although we had expected unmanaged bone yards to be picked up in the spring model, this attractant had a strong impact on the odds of conflict in the annual model. This was likely a result of the annual model having a larger sample size compared to the spring model and was better able to estimate parameters with more information based on all 178 conflicts. It is also highly probable that unmanaged bone yards were associated with conflicts mainly due to the locations of unmanaged bone yards near other attractants. Additionally, livestock producers may use unmanaged bone yards throughout a year and were thus associated with conflict locations in the summer and fall. According to our analysis, managed bone yards were not

associated with conflicts. In fact, the fall model indicated that for every 1 km distance increase away from a managed bone yard, the odds of conflict decreased. This variable did not show up in the annual model and we don't have a good explanation as to why this showed up in the fall model, particularly when this model relied on a small sample of conflicts (n=35) for parameter estimation.

Unfenced Beehives and Fenced Beehives

We accounted for the date at which a beehive site was established, season of use, and when a site had been protected using solar power electric fencing to deter grizzly bears. With this information we accounted for the development of new beehives and associated protection status of each site for each year of the study time frame. This effort did result in the finding that unfenced beehives increased the likelihood of conflicts with grizzly bears. Surprisingly, the presence of fenced beehives also increased the odds of conflict. While there is evidence that electrically fenced beehives deter grizzly bears (Madel, 1996), there is also evidence that fenced beehives may continue to be investigated by foraging grizzly bears (M.J. Madel, per. comm. February 10, 2003). It is likely that since bears may investigate fenced beehives despite being electrified, that they should still be considered a potential attractant and that spatially proximate conflicts could be indirectly related to the locations of fenced beehives, depending on the availability of other attractants located nearby. Beehives along riparian corridors were among the first in the study area to be electrically fenced in the late 1970s and early 1980s by the local honey producer and later with the help of MFWP as a response to damage to hives by grizzly bears. These beehives are also near myriad attractants like unmanaged bone yards, calving areas, and spring cow/calf pastures. Thus, conflicts

associated with other attractants, but near fenced beehives, may have been attributed to the beehives in the model process.

Calving and Lambing Areas

The presence of calving areas also appears to increase the likelihood of conflict, particularly in the spring. Conflicts appear to be associated with times when livestock were most concentrated and with highly vulnerable neonates. The majority of livestock producers in the study area “open-calve” or use a combination of corrals, barns, and adjacent pastures for the 60 to 70 day calving season that typically begins in February and ends in late April or early May. Lambing also typically occurs during April. This timing overlaps with the emergence of grizzly bears from their dens and likely influences the ability of grizzly bears to find and prey on calves and sheep (Aune and Kasworm 1989).

The predictable locations of calving pastures and vulnerability of calves also probably affects likelihood of grizzly bear depredation. Previous studies have found that grizzly bears have specific preferences for particular species and age classes of livestock. Apparently the order of preference from highest to lowest is approximately: swine, ewes, lambs, calves and yearling cattle, cows, horses, and bulls (Mattson, 1990). The vulnerability of calves and ewes may also be a result of size preference, local bear densities, cover, and how closely animals are monitored (Mattson, 1990). Calves may be especially vulnerable to predation during “turn-out” or movement of cow-calf pairs from the calving areas to spring pastures. Calves are small and have had limited experience with predators. Additionally, calving areas can contain afterbirth and it is not uncommon for grizzlies to find and consume this source of protein (M.J. Madel, per. comm. February

10, 2003). The concentration of animals in calving and lambing areas may also be a strong olfactory attractant and may draw foraging bears into potential conflict situations.

Grizzlies that are attracted to calving and lambing areas are likely to be near ranch residences and as a result, may find other human-related foods that can lead to conflicts. Moreover, the majority of calving areas in the study area have been used for decades, making this attractant highly spatially predictable. Lambing areas tend to be located near calving areas in our study area and are equally predictable in their location.

It is also worth noting that in early model phases, we found that density measures of cow/calf pairs and ewe/lamb pairs did not contribute to the model selection (see Appendix A). While we included this in our model work thinking that it may have been a useful means to establish the relative difference or a possible threshold that led to an increase in conflict likelihood, it appears that the mere presence of calves and lambs in combination with other attractants are more important than density.

CONCLUSIONS

After accounting for the presence of riparian vegetation, a collection of attractants influenced the likelihood of conflicts. There were seasonal and year-round dimensions to this collection of attractants that were concentrated together in hotspots. In our previous work we identified and described conflict hotspots where a majority of conflicts occurred during 1986-2001. We also found that specific hotspots shared spatial overlap from season to season and shared common features and attractants; namely having riparian vegetation present and having year-round attractants like bone yards and beehives available to foraging grizzly bears. These overlapping hotspots accounted for 62% of all conflicts. It appears that general patterns of conflict can be explained by contexts where

beehives and bone yards are available year round or provide a type of “background” condition that is attractive to grizzly bears. This background attractant condition is likely magnified as season-specific attractants become available from one season to the next, creating consistent patterns of available attractants that lead to repeated conflicts. The additional component that is vital for understanding hotspot formation is that all of the seasonal and year-round attractants found in spatially overlapping hotspots are found close to one another. The importance of the logistic regression model results to understanding hotspots is that seasonal attractants such as spring calving areas, lambing areas, and spring sheep or cattle pastures played a time-specific role as did sheep and cattle summer and fall pastures in explaining conflicts. Moreover, unmanaged bone yards and both unfenced and fenced beehives were year-round attractants that increased the likelihood of conflicts.

Perhaps the most important result of our model analysis is that a collection and concentration of attractants located nearly one another appear to be the key ingredients that help explain broad patterns of conflicts. Each additional attractant found in a particular context makes these sites that much more attractive to grizzly bears and elevates the likelihood of conflict. While isolated attractants may lead to occasional conflicts, the majority of conflicts (75%) over a 16-year period were found in distinct clusters where multiple attractants were available to grizzly bears. Identifying, predicting, and responding to conflicts in a landscape can be systematically accomplished by prioritizing conservation and management efforts to contexts where the greatest number of attractants are found in close proximity to one another.

Results from our contour probability plots and Hosmer-Lemeshow goodness-of-fit tests for all models showed generally adequate predictive capacity and have importance for spatially explicit management, for further inquiry, and for limited predictive use in other ecosystems where similar ecological and land uses occur.

CHAPTER 8: CONCLUSIONS AND MANAGEMENT RECOMMENDATIONS

KEY FINDINGS

Human-grizzly bear conflicts on private agricultural lands are, in part, a product of historical ranching settlement patterns and current management practices that seasonally concentrate agricultural attractants in specific contexts along riparian corridors. Livestock and beekeeping production along river and creek bottoms have resulted in problematic configurations of attractants in specific contexts. These configurations were characterized by distinctly clustered arrangements of multiple livestock pastures, bone yards, and beehives. The concentration of attractants near one another lures foraging grizzly bears into these preferred contexts where food rewards may be obtained. Certainly isolated attractants can lead to conflicts. However, our analysis suggests that the bulk of all conflicts were concentrated in specific contexts where there was the greatest density of attractants were clustered together in specific portions of the study area. We dubbed these contexts “conflict hotspots” based on our own normative definitions and identification protocol. We found that discrete seasonal conflict hotspots accounted for a majority (75%) of conflicts during 1986-2001. Subsequently, this work has helped to clarify the relative scale at which most human-grizzly bear conflicts have occurred on private agricultural lands. The seasonal hotspots we defined and identified, made up approximately 8% of the study area after accounting for spatial overlap of hotspots.

It was evident that a collection of seasonal and year-round attractant sources that were found in close proximity to one another and were predictably found in the same locations from year to year, led to the formation of conflict hotspots. We found through

Monte Carlo (MC) simulations, that conflicts were strongly associated with rivers and creeks. Sheep lambing areas and spring and summer sheep pastures were also strongly associated with conflicts. Cattle calving areas, spring cow/calf pastures, fall pastures, and bone yards were also associated with conflicts. Our MC simulations to test if beehive protection status was associated with conflicts were inconclusive. However a chi-square test suggested that protected (fenced) beehives were less likely to experience conflicts than unprotected beehives. Conflicts also occurred at a higher rate in riparian and wetland associated vegetation than would be expected under an assumption of spatial randomness.

Additionally, seasonal conflict hotspots were not the product of a few “problem bears.” There were 22 individual grizzly bears associated with seasonal hotspots and an additional 92 conflicts among the seasonal hotspots that were not attributed to unique individuals. It is likely that additional individual grizzly bears were associated with the seasonal hotspots.

We also found commonalities among hotspots that had distinct spatial overlap. In other words, there were hotspots that shared a geographic location and were a chronic locus area for repeated conflicts over time. In fact, we found that overlapping hotspots accounted for 62% of all conflicts and that these contexts all had riparian vegetation and the year-round attractants, unmanaged bone yards and beehives. These contexts experienced seasonal influxes of livestock also in close proximity to the year-round attractants and influenced the patterns of conflicts we observed in hotspots. It is likely that year-round availability of attractants like unmanaged bone yards and beehives found in close proximity to one another provided a background level of available attractants

attractive to grizzly bears. When these attractants were coupled with the addition of spatially concentrated seasonal attractants all in close proximity to one another, conflict hotspots resulted. This was particularly evident in chronic hotspots i.e., those we identified as having more than 4 years (in total) with conflicts. Chronic hotspots had some of the greatest concentrations of attractants available to grizzly bears in the study area and accounted for 58% of all conflicts.

Patterns of conflict in the study area were not simply a product of having livestock in grizzly bear habitat. We found that many parts of the study area had riparian vegetation and available attractants like calving areas where one would expect conflicts to occur; yet few in any did. We suggest that contexts such as these did not have the necessary collection of year-round and seasonal attractants that characterized overlapping seasonal hotspots. Apparently, isolated attractants even in productive habitat are less likely to be targeted by grizzly bears than are contexts where both year-round and seasonal attractants are concentrated and consistently available.

Our univariate results were helpful in addressing the likelihood that the locations of landscape features and attractants and conflicts do not appear to be random. However, these tests were carried out on a case-by-case basis and should be tempered by that fact that univariate analyses can not adequately account for the confounding effects of multiple features and attractants like the presence of calving areas, sheep pastures, unprotected beehives, and bone yards (carcass dumps) that might all be located in close proximity to riparian areas and be found across seasonal hotspots. Nor did could the univariate analysis address the *relative strength* that features and attractants might play in assessing the likelihood of conflicts at the seasonal or annual time frames. Additionally,

Monte Carlo (MC) tests did not adequately account for temporal changes in management practices like beehive protection status or bone yard management.

The logistic regression models we developed had importance for addressing the relative contribution that multiple variables had on the likelihood of conflicts. *After controlling for the strong influence of riparian vegetation*, it was clear that a collection of seasonally available and year-round attractants had strong effects on the likelihood of conflicts on private agricultural lands. Our model also showed that the collection of attractants had an additive effect on the likelihood of conflict. In other words, each additional attractant makes a particular location that much more attractive to grizzly bears above and beyond being located near or within riparian areas. This confirmed the relative importance of attractants in affecting the odds of conflict and suggests that *conflict occurrence was not just a result of being located in proximity to productive bear habitat*. We found that seasonal attractants such as spring calving areas, lambing areas, and spring sheep or cattle pastures played a time-specific or seasonal role as did summer and fall sheep and cattle pasture locations in explaining conflicts. Moreover, unmanaged bone yards and both unfenced and fenced beehives were year-round attractants that increased the likelihood of conflicts. It was apparent that this collection of attractants increased the likelihood of conflict and provides evidence that the strong spatial patterns of conflicts found in seasonal hotspots appears to be associated with a concentration of year-round and seasonal attractants.

Additionally, contour probability plots of the logit transformation from the seasonal and annual models had generally good overlap with the actual distribution of conflicts during 1986-2001. In other words, the predicative capability of the model fit

generally well with the observed phenomena. We acknowledge that some contexts in the study area had few if any conflicts and contradicted seasonal and annual model predictions. In other words, there appeared to be the necessary collection of concentrated attractants but few conflicts. These contexts warrant further analysis to study less tangible factors that are important to understanding conflicts like rancher attitudes towards bears, animal husbandry practices that may minimize conflicts, or the possibility that conflicts were occurring but not being reported in these areas.

MANAGEMENT RECOMMENDATIONS

Landscape Level Recommendations

There has been little spatial analysis of human-grizzly bear conflicts on private agricultural lands in North America. Within landscapes that support grizzly bears and have well defined riparian corridors; management efforts should be focused within a 1.8 km buffer of rivers, creeks, and wetlands. Or, if there are data available on conflict locations, mapping of conflict densities within riparian areas can direct managers even more precisely to specific problem areas and make efficient use of scarce resources. Seasonal density surface mapping can guide management efforts by accounting for variation in conflict locations by season in a spatially explicit manner. This will be useful for targeting proactive management efforts, outreach, and educational opportunities. Display of seasonal conflict maps for livestock producers and rural residents may be useful for establishing the general scale and locations where conflict can be expected. The contour probability plots based on seasonal models would also be relevant in this type of context.

In certain areas, ranching may not be worth the inherent risk of enduring chronic conflicts with grizzly bears. However, I recognize that for a variety of reasons, many livestock producers would not choose to cease or limit their agricultural livelihood. In these cases, specific management actions are necessary to prevent and minimize conflicts between humans and grizzly bears. It may be productive to identify land ownership and attractant sources and tailor management actions to fit the social and ecological context of particular conflict hotspots. For example, several conflict hotspots found in the study area had attractant sources that can be traced to cow/calf ranching operations, commercial honey production, non-agricultural residents, and hobby ranchers. Conflicts may continue to occur without collective action on the part of private landowners and land managers in these contexts. Understanding the unique economic conditions and management objectives of individuals should be a precursor to designing collective, spatially explicit, management plans. Moreover, site-specific changes in management practices may be an effective starting place for reducing human-grizzly bear conflicts over broader scales.

Conservation easements can be an effective management tool that provides economic benefits to landowners and can lower conflict and mortality risks for grizzly bears. Easements with specific livestock management provisions designed to minimize attractant availability could be targeted for areas with high quality bear habitat that currently have problems or may have them in the future.

Livestock and Beehive Management Recommendations at the Site Level

Bone Yards

The carcass redistribution program currently employed by MFWP grizzly bear managers along the Rocky Mountain Front and southern end of the Northern Continental Divide Ecosystem has proven to be a successful technique that has helped reduce human-grizzly bear conflicts (Madel, 1996). Managed bone yards were those that were part of the MFWP carcass redistribution program where carcasses were picked up from bone yards on ranches in early spring thus eliminating the attractant source. Carcasses are randomly relocated to remote locations on the RMF where they likely serve as an important source of protein for grizzly bears after den emergence (Madel, 1996).

Unmanaged bone yards were those where livestock carcasses were simply left to decompose and were available to scavengers. Results from this research showed that unmanaged bone yards were a key factor that led to an increased likelihood of conflicts based on MC simulations, density surface mapping, and in the annual logistic regression models. Despite budgetary shortfalls for state wildlife management agencies and limited personnel, carcass redistribution and or carcass removal should be continued and expanded in ecosystems where bone yards pose risks of conflicts for grizzly bears and humans. In the study area, I estimate that there are approximately 30 to 40 remaining unmanaged bone yards that are not part of the MFWP redistribution programs.

Unmanaged bone yards on private agricultural lands within the Greater Yellowstone and Northern Continental Divide Ecosystem that continue to attractant grizzly bears into conflict situations should be targeted for redistribution or removal programs.

Beehives

Unfenced beehives increased the probability of conflict in both chi-square tests and in summer and annual logistic regression models. Cost-share programs developed by MFWP and the conservation group, Defenders of Wildlife, to assist honey producers by defraying the costs of installing solar powered electric fencing should be continued and expanded particularly in areas where extensive beehive damage continues. Montana Department of Fish, Wildlife and Parks reports high success rates for permanent solar powered electric fencing as a means to non-lethally deter grizzly bear (Madel, 1996). Results from this work also indicated that fenced beehives were also associated with conflict likelihood. Care should be taken to identify locations of fenced beehives and those additional seasonal and year-round attractants that could be found by foraging grizzlies. In other words, the locations of even protected beehives may have relevance for understanding patterns of conflict.

Calving and Lambing Areas and Riparian Vegetation

Based on the results of this research there are five specific management recommendations suitable at the individual ranch level with respect to calving and lambing areas and riparian areas: 1) move locations of calving and lambing areas out of riparian areas, 2) protect calving and lambing areas with electric fencing, 3) remove calving and lambing areas from grizzly bear ranges, 4) increase fencing along riparian areas to reduce frequency of contact among grizzly bears and livestock, and 5) shift timing of calving and pasture use minimize frequency of contact with grizzly bears.

Given that the presence of calving areas increased the likelihood of conflicts, livestock managers whose calving areas are in or adjacent to riparian areas might

consider moving calving areas at least 1 km away to areas with less vegetative cover. Windbreaks or semi-permanent sheds might be used to protect herds from wind and weather. Foraging grizzly bears may still find and predate occasionally on livestock even if calving areas are located away from riparian areas, but removing this attractant away from preferred bear habitat may reduce the frequency of contact among grizzly bears and livestock since evidence suggests that grizzly bears along the Rocky Mountain Front show strong fidelity to riparian and wetland vegetation (Aune and Kasworm, 1989). If a ranch operation is space limited or moving a calving or lambing area is not an option, solar powered electric fencing can be erected around these calving pastures to non-lethally deter bears. While this research did not test the efficacy of this technique with respect to calving areas, both permanent and semi-permanent fencing techniques have been used successfully to non-lethally deter large carnivores and grizzly bears in the United States, Alaska, Canada, Europe, and Africa to protect livestock and other human based attractants (Madel, 1996, Follman and Hechtel, 1990; Jonkel, 2002; Kaczensky, 1999; Kruk, 1980; Sillero-Zubiri and Laurenson, 2001).

Another option may be to locate calving pastures in less productive bear habitat. While this was not directly tested in our models, there were several livestock producers who owned or leased extensive summer pastures in the study area but calved in areas that were not frequented by grizzly bears. These producers have had few or no conflicts with grizzly bears over livestock for several decades. Yet, for many ranchers, this is most likely not a practical option nor economically feasible. Creative cost-share programs could be established among ranchers, conservationists, and wildlife management

agencies to purchase or lease lands for collective calving areas located away from grizzly bear range.

Considering that both bears and livestock tend to use riparian areas at concurrent times, fencing of riparian areas and developing off-site watering options could help ranchers minimize the frequency of contact among livestock and grizzly bears particularly near calving areas. There is very limited fencing of riparian areas in the study area to date. While riparian areas provide important forage for most ranches, late fall and winter grazing of riparian areas has been successful and could minimize the seasonal overlap among cows and bears (Ehrhart and Hansen, 1997). The Nature Conservancy's (TNC) Pine Butte Preserve employs this grazing strategy, has some of the most productive grizzly bear habitat in the study area, yet has not had any grizzly bear-livestock conflicts on the preserve since its inception in the early 1970s. It should also be noted that TNC does not allow any calving on the preserve.

Another management recommendation for livestock producers would be to shift the timing of calving from late-winter, early-spring to early summer. As natural bear foods become more available, calves may be less of an attractant and by hyperphagia (intensive, pre-denning foraging and eating by bears) in the fall, calves would be larger and stronger and less vulnerable to predation. The above recommendations for calving areas can also be applied to sheep lambing areas.

Integration of Results with Existing Wildlife Management Programs

The results from this study could be integrated into existing prevention programs used by bear managers in Idaho, Montana, and Wyoming. For example, the locations of unprotected attractants like beehives or calving areas could be compared to radio/GPS

locations of bear movements for more precise bear management applications. Spatial and temporal patterns of attractant preferences by bears may be revealed and actions could be taken to minimize those conditions that lead to conflict. For example, an individual bear may key into a specific set of calving areas or beehive sites based on a history prior food rewards. Knowing both the locations of attractants and bear movements would assist with rapid identification of areas that need rapid management responses. Additionally, as managers continue to work on cost-share programs like electrifying fences for beehives, calving areas, and sheep lambing/bedding areas, quantifying the affect of attractant protection and probability of conflict can help to evaluate management efforts and ultimately provide justification for budgetary requests by wildlife agencies.

These results also highlight the potential efficacy of targeting conflict abatement efforts in agricultural landscapes with recovering grizzly bear populations. Our contour probability plots would be a useful application in these landscape contexts. Conservation efforts in such areas should start with mapping of livestock management practices and beehives relative to existing vegetation and seasonal bear habitat. This process would help managers identify potential conflict hotspots where actions could prevent the hotspots from coming to fruition. This may be especially relevant in parts of the Yellowstone ecosystem where grizzly bear populations appear to be expanding outside of park and national forest boundaries.

Integration of Interactive Mapping Methods with Wildlife Management

The use of laptop computers and high quality digital aerial photographs to collect spatial information on livestock management practices was perceived favorably by livestock related land users, produced high quality information, and may have many

applications for wildlife managers. For example, there is no standard report form used by state, federal, and tribal grizzly bear managers for collection of information on reported grizzly bear conflicts with humans. Current discussions by the Interagency Grizzly Bear Committee (IGBC) are under way to establish a systematic data collection protocol for Montana, Idaho, and Wyoming. Often, field biologists and managers spend long periods of time working one-on-one with private landowners throughout the Northern Rockies when they respond to human-grizzly bear conflicts, engage in education and outreach, or work on specific projects with landowners. Database software has the ability to create actual field forms that are easily interpreted by different field technicians. The portability of laptops can allow field biologists to have a mobile office and streamline the data entry process. Perhaps one of the greatest advantages of using a digital data collection protocol is time saved. Currently, most bear managers use hard copy field forms to report the specifics of a conflict and assign UTM coordinates to the conflict locations on 7.5-minute topographic maps. Digital orthophotos, topographic and elevation maps can be displayed in Arc/Arc Info software to allowing conflict locations and site descriptions to be recorded in the field. The initial investment in computers and GIS training would likely be offset by time saved from the laborious process of entering field form data into databases after the fact.

Interactive mapping techniques could assist wildlife managers to establish baseline attractant maps for evaluating preventative management practices and identifying chronic conflict sites. On a broader scale, this could allow wildlife managers to systematically monitor their management efforts. For example, unprotected attractant sites can be mapped and radio locations or Geographic Positioning System (GPS)

locations of bears can be integrated into the GIS environment for better bear management. Thus, the spatial patterns of attractant preference by bears or conditioning patterns may be revealed by collecting data using our techniques coupled with spatial statistical analysis.

Laptop use in the field offers wildlife managers learning and teaching opportunities. Participants of this study were receptive to digital mapping and the display of information. For example, bear managers might use the technology as a heuristic tool when discussing a chronic conflict situation with a particular livestock related land user. If the saying “A picture is worth a thousand words” has any merit, showing someone a conflict cluster on their property that spans 10 years, for example, may be an incentive for changing management practices or adopting a proven deterrent technique like electric fencing of sheep bedding yards. Moreover, showing a person the context of their property in the greater landscape with respect to overall conflict locations may be helpful for collective action that serves the common interests. Interactive mapping could also allow wildlife managers and rural landowners to work one-on-one to systematically discuss the spatial conditions on ranches that may predispose a particular operation to conflict.

LIMITATIONS OF THIS STUDY AND FUTURE RESEARCH NEEDS

This research could have been improved by incorporating a larger sample size of reported human-grizzly bear conflict and mortality data beyond the boundaries of the study area. A larger sample size would have increased the reliability of parameter estimates in our model analysis and may have helped to establish types and or patterns of conflicts that led to eventual grizzly bear deaths. We could not detect these types of

patterns since grizzly bears had conflicts outside of our study area and we did not have access to these data.

Models of any complex phenomena are limited by the assumptions and model parameters that are used for analysis. We assumed that seasonal livestock pasture arrangement data collected in 2001 generally represented the locations of pastures during 1986-2001. We recognize that site-specific complexities of land use are often dynamic and that livestock producers may rest and rotate their pastures to ensure regeneration of their forage base. It would have been ideal to have a complete land use history of pasture use that detailed locations for each season of all 16 years of the study. However, this level of detail would have placed excessive time burdens on the ranchers and was impractical. Locations and use of seasonal pastures as indicated by ranchers are a simplification of the management practices in the study area.

As we worked through our analysis and periodically shared our results with the local grizzly bear management specialist, we were told that sheep bedding yards may have been a better metric to use in terms of attractant strength than sheep lambing areas. (M.J. Madel, per. comm. May 10, 2003). Ideally, we should have collected data from livestock producers on locations of sheep bedding yards and used this in addition to sheep lambing areas. However, since sheep operations are centralized, sheep lambing areas tend to be located near sheep bedding yards, would have most likely been collinear, and subsequently would not have affected model results to any large extent.

Undoubtedly there are additional factors associated with human-grizzly bear conflicts like household garbage management, rural garbage pick-up sites, locations of residences, long-term variation in natural bear food availability, road use, recreational

access, campsite attractants, or grizzly bear population dynamics. However, a good model should approximate and abstract key factors that appear to be driving the process, system, or phenomena of interest. Most conflicts in the study area were associated with livestock management or beehive site locations and protection status and thus we focused on these activities for analysis. Yet, other factors like human attitudes and perceptions of bears and subsequent human behaviors that may predispose grizzly bears to conflicts were not addressed in this analysis. The contour probability plots provide clear spatial direction for further analysis into specific contexts where conflicts were predicted but did not occur. We have collected extensive data sets on attitudes and perceptions of grizzly bears and how bears influence landowner decision-making. We will be analyzing these data that should help build a more comprehensive understanding of human-grizzly bear conflicts for future research and conservation applications.

The results from this work are most relevant for the Rocky Mountain Front region. However even here, there is variation in grizzly bear use of private lands and in land use practices that may lead to conflicts. Thus, generalizations of these results to other ecosystems should be tempered by the fact that this work was focused on the agricultural context of the study areas. Nevertheless, many patterns from this work could provide hypotheses for other ecosystems that are dominated by agricultural land use, support populations of grizzly bears, and have well-developed riparian corridors.

The point process modeling approach used in the logistic regression analysis did not directly address spatial correlation among observed points. Future auto logistic regression modeling that incorporates these types of spatial point data that may be able to

eliminate issues of correlation. We will be exploring this approach to these data in the future.

CONCLUDING REMARKS

During the course of this research, a rancher told me that there was, “Too much deep thinking going on in Missoula” and that, “Grizzly bears should be managed like elk.” Whether this individual was making an oblique reference to Norwegian philosopher, Arne Naess’ work on deep ecology, or was simply poking fun of the academic and conservation community in Missoula, I took his remark as a positive indication that there is the perception that conservation biologists, activists, academics, and citizens were doing their jobs—to think deeply about ways to live more lightly upon the land. I believe that it is our responsibility to find ways to coexist with species like grizzly bears. Living with grizzly bears requires courage, creativity, and humility; admirable qualities that I have seen in rural residents and ranchers whose land ethics include grizzly bears. The Roman scholar, Pliny the Elder, writing nearly 2000 years ago said that wild things like bears and wolves were the protectors of wild places. I think that bears may also be unrecognized protectors of our collective minds. Bears may serve to protect and strengthen the human spirit by reminding us to find the humility to adapt and to belong to rather than hold dominion over the greater ecological community.

Writing more than 50 years ago, Aldo Leopold suggested that grizzly bears pose a crucial test of a community’s commitment to conservation. Minimizing conflict and mortality risks to grizzly bears on private lands will require partnerships and communities of landowners, scientists, managers, and conservationists to think deeply with humility

about ways to pass this important test. Surely our commitments will be honored by future generations if we have the will to try.

APPENDIX A

Early Model Work

In the early modeling stages we used an exploratory, stepwise modeling process using log likelihood values to eliminate landscape feature and attractant variables that were collinear with one another or were clearly not adding relevant information regarding the likelihood of human-grizzly bear conflicts (Hosmer and Lemeshow, 2000). This was done in order to reduce the total number of variables to a plausible set (see Chapter 7, Table 7.1) for use in model selection using Akaike Information Criteria (AIC) where dozens of models were compared to one another. Since AIC model selection is a time consuming and iterative process, we wanted to use the most relevant set of variables possible to avoid redundant and or extraneous variables. We eliminated 12 variables based on this early exploratory work (Table A-1.1).

Table. A-1.1. Variables eliminated in early exploratory model phase.

<i>Description</i>	<i>Season</i>	<i>Variable Type</i>
Landscape Feature Variables		
River and Creeks		
Distance to nearest river and creek edge (m)	Non-seasonal	Continuous
Landsat Image for Vegetative Cover Types		
Percent Agricultural cover type within a 1.6 km search radius	Non-seasonal	Continuous
Percent Barren cover type within a 1.6 km search radius	Non-seasonal	Continuous
Percent Cloud cover type (no data) within a 1.6 km search radius	Non-seasonal	Continuous
Percent Forest cover type within a 1.6 km search radius	Non-seasonal	Continuous
Percent Shrubland cover type within a 1.6 km search radius	Non-seasonal	Continuous
Percent Upland Grassland cover type within a 1.6 km search radius	Non-seasonal	Continuous
Percent Urban cover type within a 1.6 km search radius	Non-seasonal	Continuous
Percent Water cover type within a 1.6 km search radius	Non-seasonal	Continuous
“Core” Grizzly Bear Habitat		
Distance to “core” grizzly bear habitat (m)	Non-seasonal	Continuous
Agricultural Attractant Variables		
Density of cow/calf pairs in calving areas (n/km ²)	Spring	Continuous
Density of Ewe/lamb pairs in lambing areas (n/km ²)	Spring	Continuous

The remaining variables that were used for analysis are found in Chapter 7, Table 7.1.

Overview of Landscape Feature and Agricultural Attractant Variables

For landscape features variables, we used a digital vector based hydrography layer at 1:100,000 scale to represent rivers and perennial creeks in the study area (NRIS, 2001) and 30-meter pixel resolution Thematic Mapper Landsat data for northern Idaho and western Montana (Redmond et al. 1996) to account for broad vegetation conditions in our study area. Distances of conflicts and random points to nearest rivers and creeks were measured to the nearest edge and we used a 1.6 km search radius to assign the percent of each cover type within the 1.6 km search radius when a conflict point or random point was present in the search radius.

We defined “core” grizzly bear habitat as all areas contained within bear management units (BMUs) that bordered or occurred within the study area. BMUs were designed in part to accommodate sufficiently diverse habitats to support all seasonal needs of grizzly bears (C. Servheen, per. comm. May 6th, 2003). BMUs were also designed as analysis areas for a cumulative effects model (CEM) that was used to assess impacts to key grizzly bear habitats. We calculated the Euclidean distance to core habitat from each conflict and non-conflict point to represent the probable diminishing odds of grizzly bear activity the farther a point was from a “core” habitat. There did not appear to be any relationship with annual and seasonal locations of conflicts and core habitat over the 16-year study time frame. While the delineation of “core” habitat is somewhat arbitrary, there were no data on aggregated grizzly bear home ranges that could have otherwise been used for this delineation.

Livestock related land users also provided the average number of livestock they raised annually during 1996-2000. We used these data to assign densities of cattle and sheep during calving and lambing seasons. We chose to represent only livestock density during the calving and lambing season because the much larger sizes of other seasonal pastures made densities unmeaningful. In cases where a livestock producer had more than one calving or lambing area, we divided the total number of animal pairs equally among them. We acknowledge that there was error associated with this variable namely that numbers of animals may have changed over the 16-year period and we used only data based on a 5-year average. We also assumed that livestock producers would evenly distribute animal pairs among calving areas. We found that 40% of livestock producers had more than one calving area and that these areas were roughly equivalent in size, suggesting that our assumption of even distribution was not too improbable. However, it would have preferable to have obtained the exact number of animal pairs that were put in each specific calving or lambing area.

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